PHILIP REIS.

THE JOURNAL

—OF THE—

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS,

PUBLISHED BY

THE INSTITUTE,

UNDER THE DIRECTION OF THE COMMITTEE ON PUBLICATION.

VOL. CXXI.—Nos. 721-726.

THIRD SERIES.

VOL. XCI.—JANUARY TO JUNE, 1886.

PHILADELPHIA:

FRANKLIN INSTITUTE, No. 15 SOUTH SEVENTH STREET.

1886.

JOURNAL OF THE FRANKLIN INSTITUTE.

Vol. CXXXI.

INDEX.

// JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXI. JANUARY, 1886. No. 1.

ON TELEPHONE SYSTEMS.

By PROF. AMOS E. DOLBEAR.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *Friday, December 11, 1885.*]

Mr. President and Members of the FRANKLIN INSTITUTE:—The subject of the telephone is not so old as some other subjects that might be named, but within the past ten years it has engrossed so much attention in the way of experiment in all civilized countries, and has been the text for so many discourses that it is hard to find anything that shall be new to such a body of listeners as I have before me. I cannot hope to add to your knowledge, and my aim will therefore be to summarize the principles that underlie telephony, and the methods that have been adopted in developing it.

I would first remark that when any physical end is to be reached, there are certain physical conditions which must be recognized, viz., the laws of matter and of energy. There can be nothing accomplished in the physical world without it. Matter always is subject to its own laws, and the relations of matter to energy are such that no transformation of the latter ever takes

place except through the agency of matter. Indeed, it would be true to say that the body of physical science is made up of statements of the conditions under which energy is transformed.

We may call these the laws of nature; they are the conditions under which we live and to which we must conform, for a physical law can never be traversed. A balloon rises in the air not in spite of gravity, but on account of gravity. The pressure of steam is due to molecular impact, and if the molecular velocity be great enough, the boiler bursts. If the railroad train is to be run fast there must be no short curves in the road, for Newton's first law threatens disaster to such a combination.

Physical relations or laws then are fundamental, and every working machine works in accordance with them, whether the maker understood those laws or had them in mind or not. In the days when the commonly held theory of heat was what is now known as the Caloric theory, the steam engine worked just as it does now, and the development of the kinetic theory of gases, and a clearer understanding of heat phenomena has not affected the motion of a single molecule. Clearly then individual *intention* has nothing to do with physical laws involved in any piece of mechanism.

All mechanical devices embodying energy are either transformers, transferrers or governors. A furnace is a *transformer* of the chemism of coal and oxygen into heat. The boiler is a transferrer of heat to the water endowing it with greater molecular energy. The engine is a transformer of the heat energy into visible mechanical rectillinean and rotary motions, while the main shaft is again a transferrer of rotary energy to the distant room where, through the agency of pulleys and belts the transformations are chiefly such as change the character or direction of motion, converting rotary into reciprocating motion, or *vice-versa*, etc. In like manner a galvanic battery is a transformer of the energy of zinc and acids with electrical energy. The leading wires are transferrers, conducting the electrical energy where it is needed, while the relay or sounder is again a transformer of the electrical energy into mechanical motions of an armature which may record its own movements, or the latter may be interpreted at once by an experienced listener. If a Morse key be put in such a circuit, it is as a controller of the transformations, and of course of the transference as well. It neither adds to nor subtracts from the energy, it simply

controls it. So long as the Morse key is manipulated by hand, the electric energy available is subject to the will of the operator, only however in its *rate of delivery*, not as to its generation, its velocity of transmission or its transformations in the sounder. Those are the physical relations which are beyond the reach of any intention, and could not be changed by any will or wish the manipulator might have.

It is, however, possible to make an automatic governor or key which shall so control the electricity as to produce a set of signals similar to those made by hand, but this automatic device is built upon physical principles, has its own laws of working, and, *while it is working*, is not subject to any one's dictation or will or wish. If it does its work properly it is because it is made in accordance with the laws of matter and of energy, which are concerned in its working, whether the maker knew all those laws or not. It is as true for such a piece of mechanism as for a boiler injector or the governor of a steam engine. These principles or laws are simply *adopted*, not adapted; the mechanism is always *adapted* to the principles or physical laws which are to be operative, and it is right that the distinction between physical laws and the apparatus through which transformations of energy or the control of energy, are possible, should not be lost sight of, for I have known where the statement of the recognition of a physical law in the sense in which I have described it, has been made as a claim upon the physical law itself. The law has allowed it, and the court has awarded it.

What, then, are the physical conditions which underlie the electric transmission of speech? Speech,—articulate speech—consists of sound vibrations in the air, generally of a highly complex character. The sounds themselves are partly arbitrary and partly automatic; that is, what I call a tree a Frenchman would call *l'arbre*, and a Chinaman something else. So much is purely arbitrary, but there is a difference,—a physical difference between my word tree and your word tree, which no amount of pains taking on my part could make identical, the character of my voice is not subject to volition; it is as automatic as the sound of a violin or of a cornet, and that for the reason that the instrument that produces it is a physical instrument, having its own laws of vibration and resonance. The pitch may he varied, but not the quality, and so

it is for a cornet or a violin. Articulate sounds are the arbitrary ones, and have no particular character like musical instruments, no particular series of harmonics belongs to speech, but articulate sound vibrations in air involve *energy*, and can only be maintained by the expenditure of energy and any question of the transference of such vibrations from one point to another, is simply a question of energy. If the distance be not too great, there may be enough energy in the vibrations in air to affect the auditory nerve of a listener, and no transformation will be needed. If the sound-waves are prevented by a tube from spreading spherically in space, the energy will not be so wasted and the sounds be heard at a greater distance, but there is a limit there, and if speech is to be rendered at a greater distance, apparatus for transformation and transference must be employed. If electricity is to be used, then the relations, if any, between sound vibrations and electrical phenomena must be employed. We might be supposed to know that electricity quickly distributes itself in a metallic circuit, and also that a Morse key enables one to send electric pulses at will through an electric circuit. But a key that will respond to sound vibrations *must necessarily be automatic*, for no hand can move with the rapidity and variety of sound vibrations. When sound vibrations fall upon any surface they impart a portion of their energy to it, and cause it to vibrate in a similar way. One may whisper close to a closed door, and be heard by one whose ear is against the other side of the door. The smaller and thinner the surface against which such sound-waves spend themselves, the greater will be the amplitude of the movements. Let such a surface, capable of responding to any sound vibration, be provided with freely moving electric terminals, so that every vibration shall send into the wire a corresponding electric impulse or wave, and we have a device that will do for speech in an automatic way what the Morse key will do when manipulated by hand, namely, vary the strength of an electric current in the circuit in accordance with certain arbitrarily chosen symbols. Such a device is now generally called a transmitter, but in reality it is an automatic governor, as its function is to control an electric current operated by the variable energy of sound-waves. So far as the apparatus described does what has been said, we have an electric circuit in which the electric energy is a variable quantity depending upon the vibratory movements of

the tympanum, and this may be from the maximum quantity which the provided conditions permit, to nothing if the current be entirely broken.

With the Morse key, this range is reached for each signal; with the other, the range cannot be so great without danger of omitting some of the vibrations that constitute the sound. The sound vibrations in the air are a series of continuous waves so long as the sound is being produced. If the velocity of sound in air be, say, 1,125 feet per second, and if a sound of any kind be produced for, say, one second, then the first wave will be 1,125 feet from the last wave, and between them will be an unbroken series of similar ones. If such a series had acted upon the terminals of the electric circuit, the same unbroken series of electric waves would have been produced.

WHAT IS A SYSTEM?

A system is a series of steps or processes employed to attain some end or accomplish some purpose. Some things may be done with a single movement, yet there are few things that may not be done in more than one way. A tree may be cut down with an axe, or sawn down either by hand, or by a circular saw run by steam, or it may be burned off by a platinum wire made red-hot by electricity, or it may be gnawed off by beavers.

If time is to be kept, it must be by some *uniform movement*, which may be secured by a pendulum or balance wheel, each in train with a set of gears and a weight or a spring. The end attained is the same, but the steps are different, and these may properly be referred to different systems or methods. Uniformity of action is the physical, necessary condition for time-keeping, but uniformity of action is not a method of time keeping.

If the early maker of a pendulum clock had said: "I have discovered that in order that time should be kept, it is necessary to have a uniform, mechanical movement, and I have invented a pendulum to effect this; I, therefore, claim the method of and the apparatus for time keeping;" if some patent office had granted such a patent, and if the courts had upheld the claim, the case would be paralleled by the celebrated fifth claim of the famous telephone patent of 1876. It might be true that no one had stated the condition so tersely before, yet the Clepsydra embodied the proposition and astronomers had predicted eclipses on the

basis of uniform motion for time keeping for thousands of years before.

Morse proposed a telegraphic system consisting of a battery, a key, a transferring wire, and an electro-magnet, with a movable armature, which should record its movements. Not one of the steps was original with him. He invented neither battery, nor key, nor conducting wire, nor electro-magnet, but he combined these in such a way as to produce valuable results, at distances which had not been reached before. Bain proposed a telegraph system, in which a battery, a key, a wire, and an electro-chemical instrument were employed. Neither of these steps did he invent. The differences were, briefly, that where Morse employed magnetism and its mechanical relations, Bain employed chemism and its optical relations. One embossed paper, the other made a blue mark upon it. But the differences were deeper than this, for the battery-power needed to do the work was much less in Bain's than in Morse's, and, moreover, there is a limit to the speed with which an armature of a magnet can move, and, therefore, a limit to its telegraphic speed, but there is no such limit to the speed of such chemical reactions. Indeed, the only reason I ever heard for the abandonment of Bain's system was its unnecessary delicacy. In each of these systems, the electricity which was to do work was fitted at the transmitting end for the work it was to do at the receiving end, and the movements, of whatever sort, at the receiving end, had corresponding motions of the key. Then there was the Dial system of telegraphy, wherein a finger moving round a dial caused a similar movement of a finger about a receiving dial. In each and all systems, it was recognized as a physical necessity that if electricity was to do a certain work, it must be fitted for it at the transmitting station. If dots and dashes are wanted, they must be made at the transmitting station. The wire is employed simply as a transferrer, not as a transformer, and if it has such a transforming property, its efficiency as a conductor is so much impaired, the amount of energy it can transmit in a given time is less, and the characteristics of the energy are more or less effaced.

It is not, then, singular to the telephone that the characteristics of the energy needed at the receiving end should be given to the electricity at the transmitting end, but on the contrary, it is the physical condition that underlies all electrical apparatus what-

ever and depends solely upon the laws of the transformation and conservation of energy, and must be conformed to, as any other laws must. To give a new crook to a magnet, or vary the relations of mechanical details in a transmitter, and call them a new system, is, to me, as ridiculous as it would be to paint the parts some different color and then christen it a new thing. That is not saying but that such changes may be improvements, but so long as the series of changes is precisely the same, from beginning to end, in both transmitter and receiver, I do not recognize the appropriateness of calling anything a new system. A different set of changes, involving different transformations of energy, different laws requiring different apparatus, I do call a different system, and these must belong to both transmitter and receiver.

In conformity to this, what are the possible ways by which sounds of any sort may be electrically transmitted and reproduced at another place?

(1.) As to the so-called transmitter, or the device for fitting the electric energy for the work it has to do. There are two ways in which electric energy in a given circuit may be controlled. (I) By varying the resistance, and (II), by varying the electro-motive force in it. If there be any third way, I do not know of it. If, then, the energy of sound-waves can be so utilized as to vary the resistance in an electric circuit in conformity with the varying phases of the sound-waves, we shall have one method, and as there is to be no transformation, it is evident that the action will be wholly mechanical, for the sound vibrations themselves are but mechanical movements in an elastic medium, and if there be no transformations, the last term of the series will be mechanical in the same sense.

If sound energy can be made to vary the electro-motive force in a circuit, without changing the resistance in the circuit, then we shall have another and a different kind of transmitter. The discovery of magneto-electricity make it possible, and some of the very first magneto-electric experiments pointed out the way, namely, the generation of electric cnrrents by means of the motion of the armature of a magnet.

(2.) As to receivers. The range of possible receivers is not restricted as is that of transmitters and a great number of ways of utilizing the electrical energy that has been properly adapted by

a transmitter have been devised. It will be well here to recall the various effects which electricity is competent to produce.

(I.) Electricity is competent to affect a magnet, which tends to set itself at right angles to the wire through which the current flows. Ordinary galvanometers are constructed to utilize this action of electricity.

(II.) Electricity is competent to produce a magnet, and upon this property the common electric telegraph and hundreds of other applications have been founded.

(III.) Electricity is competent to decompose compound chemical substances, as for instance, water; and for the utilization of this property of electricity, a common and simple one is the production of a blue mark by means of the decomposition of the ferro-cyanide of potassium as in Bain's electric telegraph.

(IV.) Electricity is competent to deposit one metal upon another metal, and from this property has grown up the great industry of electro-plating.

(V.) Electricity is competent to produce heat, the highest temperature which man is able to produce at present is that in an electric arc, and is used for the fusion of refractory substances, such as platinum, gold and steel.

(VI.) Electricity is competent to produce light, and the two systems of electric lighting, namely, that by the arc and that by incandescence, are developments of the possibilities in that direction.

(VII.) Electricity is competent to reduce the friction between bodies, and this property has been utilized by Edison in one of his telegraphic systems.

(VIII.) Electricity is competent to produce either heat or cold at a junction of metals, according as the current flows this way or that, which is known as Peltier's phenomenon.

(IX.) Electricity is competent to produce various physiological effects, and is extensively used as a therapeutic agent.

(X.) Electricity is competent to give a tortional strain to a conductor through which it flows, either right handed or left handed, according as the current is towards or away from the observer. This has been used to measure the strength of the current flowing through the wire as a kind of galvanometer.

(XI.) Electricity is competent to produce very various gaseous

phenomena, and a visible motion of paddle-wheels, by the impact of gaseous molecules, as is exhibited in various forms of Crooke's tubes.

(XII.) Electricity is competent to twist a ray of light in air or other transparent medium, but this is at present used, so far as I know, only in the investigation of physical phenomena among molecules.

(XIII.) Electricity is competent to produce in the non-material substance, called ether, a certain condition, which is generally known as the electric field, a field within which various interesting phenomena are manifest, and which are at present the subject of investigation by physicists.

(XIV.) Electricity is competent to produce a noise or sound by disruptive discharge, as in the phenomena of thunder storms and on a small scale by electric machines and Leyden jars.

(XV.) Electricity is competent to produce attraction, but this phenomenon, which has been known perhaps longer than any other of an experimental electrical kind, has not been utilized to any considerable extent.

It is not improbable that there are other things which electricity will do, which I have not enumerated, or that will hereafter be discovered. It is possible to make nearly every one of these effects available in a telephonic receiver.

It is not my intention to undertake any settlement of historical matters in connection with the telephone, nor to enter upon any questions of priority, and the names which I shall employ to designate the different systems I describe, I only adopt for the sake of distinctions which exist, and these can be more easily kept in mind if so individualized, than in any other way.

Farrar, of Keene, N. H., discovered in 1851, by experiments with electro-magnets and vibrating reeds that completed and broke an electric circuit, that the magnet was capable of responding

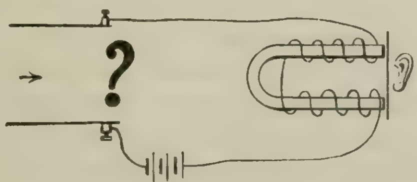


FIG. 1.

simultaneously to several distinct series of such reed vibrations, and that suggested to him that if he could contrive to vary the electricity in the circuit by voice vibrations, as he did with the reed vibrations, that he could electrically transmit speech. He was not able to devise an appropriate transmitter, and was discouraged from the attempt by the expressed opinion of the impossibility of doing it by Prof. Silliman. He had, however, the receiver, and had proved its ability to act in the way proposed. I cannot allude to Farrar's system as complete, for the work was but half done, and I therefore put in the place of the transmitter the interrogation point, to indicate what was lacking.

REIS'S SYSTEM.

Nearly ten years after that, Reis, of Germany, invented the mechanism that Farrar lacked, namely, an apparatus that was capable of responding to the minutest shades of acoustic vibrations, and having an automatic attachment making part of an electric circuit, the motions of this attachment, or the electrodes, as it may be called, being governed altogether by the sound-waves in the air.

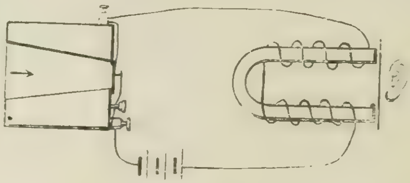


FIG. 2.

Reis made a number of transmitters, varying the mechanical details in each, but they all had in common a membrane stretched taut over an aperture, and against which sound-waves of any kind were to impinge. This membrane had fastened to its middle a thin strip or disc of platinum foil, which was connected by a wire to a binding post. Connected to another binding post was a metal strip reaching to the middle of the membrane, where a piece of platinum wire, fixed at right angles, was so adjusted by a screw as to touch gently upon the platinum disc and so complete the electric circuit with a battery, and an electro-magnet for a receiver. The energy of the sound-waves was employed to control the electric energy in the circuit, and it was expected that any change in the one would make a corresponding change in the other. That Reis

expected this, is perceived in his lecture, where he gives the curves for compound sound vibrations in air, a continuous and not a broken one, which, if it was to be transmitted and reproduced, must not have lost any of its characteristics. It is certain that he intended to have reproduced in his receiver all the characteristics of the sounds made at the transmitter. He explains the action of his transmitter as making and breaking the circuit for every vibration of the membrane, and a deal of wearisome talk has been made of late years about Reis's *intention*, one party declaring the intention to be in the function of the apparatus to transmit and reproduce sounds of all kinds with their characteristics, and they point to Reis's statement that he thus did transmit and reproduce the sounds of the piano, accordeon, clarionet, horn, organ pipes and speech. The other party declares that Reis's intention was to make and break the circuit for every vibration, and therefore he could not possibly have intentionally transmitted speech for a continuous circuit and an undulatory current are essential to do that. If, therefore, Reis did do what he says he did, it was accidentally done, and the apparatus was not working as it was intended to work. It ought to be remarked, that if the tones of the above-named instruments were reproduced, there must have been the same continuousness that is now insisted on as being essential for the transmission of speech, for the sound of a piano string is made up of a number of separate tones in harmonic series, and continuity is as much a characteristic of such sounds as of any other. But Reis distinctly says that he was able to transmit human speech, adding, "though not with distinctness sufficient for every one," which implies if anything that it was distinct enough for some. Reis explains the lack of distinctness to which he alluded as being due to the fact that the higher overtones were too weak in the receiver for all to hear, not that some of them were not present at all But that objection of a lack of distinctness was brought against the telephone of the present day. Over and over again, I have heard persons say when first listening to a telephone that was speaking well, that they couldn't hear what was said, and I dare say everyone has had a similar experience who has worked with telephones to any extent. The fact is, that nearly everyone requires some experience with a telephone before he can make out all that is said, and Reis's audience was not made up of experienced persons.

There is, however, no reason at all to doubt that Reis did transmit speech with his apparatus, for, as I have said before, the working of the transmitter is *automatic*, and depends upon the sound-waves that fall upon it, and not upon anyone's intention of how it shall do its work. Take any Reis transmitter and couple it in a circuit with a battery without anything for a receiver. Now, speak to the transmitter. Will the sound-waves vary the current strength in a proportional way? In other words, will the current be the kind known as undulatory, and one capable of reproducing the words spoken? There is only one answer to this question; there are no ifs nor buts about it. Whether they be heard or not, is another question depending upon the kind of device used for transforming the electric energy, and its degree of sensitivity, also, the acuteness of hearing of the one who listens. If an electro-magnet ill adapted to the conditions be used for a receiver, the speech might not be heard, but it would not be because the character of the work of the transmitter was at fault, but because the receiver was not delicate enough. To say otherwise, would be like denying the existence of a current of electricity in a circuit, because the needle of a galvanometer made for strong currents gave no indication of one. If it is of any importance to know whether there be a current or not, include in the circuit the most delicate galvanometer to be had. The test for the character of the working of the Reis transmitter is similar; put the most delicate receiver at hand in the circuit and listen. When such a test as that is applied, it is always found that the current from a Reis transmitter is identical with the one in common use to-day for telephonic purposes. Where this is done, however, the deniers of Reis's claim assert that the transmitter works on account of knowledge acquired since 1876, but they know better, and argue thus for commercial reasons only. Indeed, I think it proper to say here that I have conferred with a great number of electricians in various parts of the country about this matter, and there is the greatest unanimity concerning it, that Reis did invent a speaking telephone; that he used it for that purpose, and that it works in the same way as does the modern commercial telephone. A number have given me testimonials to that effect, and several who do not wish to be mixed in the controversy, express privately to me the same views precisely. The only ones that oppose it are those who have a pecuniary interest in denying it.

Reis's system of telephonic transmission consists in the employment of sound vibrations to operate upon electrodes, so as to vary the resistance at the electrodes, and thus control the current in conformity to the sound vibrations. His transmitter is more properly an automatic governor of the current, which is provided by a battery in the same circuit. His receiver consists of an electro-magnet, mounted upon a resonant case. Of these there are two varieties: One an electro-magnet without an armature, in which the varying current changes the magnetic strength, causing a corresponding molecular rearrangement, which produces the sound in air reinforced by the case; the other, an electro-magnet with an armature, provided with a spring to oppose the magnetic attraction on the one side, and a stop screw to prevent contact with the poles on the other side. The main source of the sounds in this is due to magnetic induction upon the armature, just as in the telephone of to-day. This, too, is mounted upon a resonant case. The instrument very closely resembles a common relay, the horizontal magnet, the hanging of the armature and the recoil spring are all there, and, as might be supposed, a relay makes a tolerable receiver.

Yates, of Dublin, placed a drop of water between the platinum electrodes in Reis's transmitter, and thus prevented the absolute break in the current to which Reis was liable; he also mounted the electro-magnet of the receiver in a better way, and so got

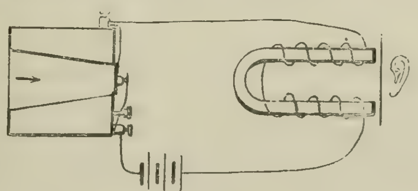


FIG. 3.

better results. Dr. Messel, of London, who was one of Reis's pupils, told me that Reis himself placed water and sulphuric acid and sulphate of copper solution, and various other solutions, in the same place and for the same purpose. This experiment of Yates, which is well enough authenticated for history and credence, teaches one lesson that has been overlooked so far in this telephonic controversy. It has been said over and over again, that if Reis had actually achieved the electric transmission of speech, that

everybody would have heard of it, that it could not have been buried and so little known of it, because the achievement was one of the highest importance, and therefore, if so little was known of Reis's speech transmission, it was because he didn't do it. But it is not denied that Yates did it in 1866, and that it was known at the time at the University there, but it did not appear to be of enough importance to even chronicle. Silence, therefore, does not tell against Reis, but against the contemporaries of Reis and Yates.

The grandest invention is of but little worth, except it be allied with business tact and energy. A steam engine is good for nothing without coal and stoking.

Elisha Gray, of Chicago, designed a speaking telephone and entered a caveat for it in the Patent Office early in 1876. The only difference between his plan and that which I have described, consists in the structure of the transmitter, which consisted of a metallic vessel, containing a liquid conductor, the top covered with a diaphragm, carrying at its middle a wire conductor, reaching

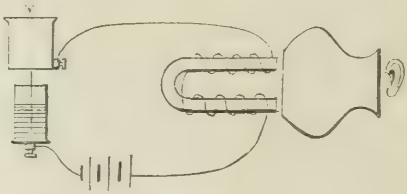


FIG. 4.

down into the liquid. This wire was made part of an electric current with the solution and vessel, a battery and an electro-magnet with armature for receiver. Any sound made at the diaphragm moved the wire in the solution in a corresponding way, and so varied the strength of the current by varying the resistance in the liquid. The receiver had the electro-magnet armature mounted upon a tube, which was advantageous for listening, as the sounds were thereby prevented from scattering to the degree they did with Reis's mounting. It did not differ in principle from Reis for the series of reactions from the sound to be transmitted, to the one that reached the ear were practically the same, namely, the air vibrations acting upon an electrode varied the resistance of an electric circuit maintained by a battery, and

the varying current varied the magnet's inductive strength upon the armature, causing it to move in accordance with such current changes.

McDonough, also of Chicago, about the same time had modified a Reis transmitter by making multiple platinum contacts, and lessening the liability to the disruption. His receiver was similar in structure to Gray's. This, considered as a system, is identical with Reis's.

Drawbaugh, of Pennsylvania, and Meucci, an Italian, both lay claim to the inventions of this system.

BELL'S SYSTEM.

Bell departed from the system already described. Beginning with the transmitter he dispensed with the movable electrodes and the variable resistance, and in the place of that apparatus he placed an electro-magnet with its armature, proposing to speak to the armature itself, which being set in, forced vibrations similar to the originating sound-waves, should react upon the poles of the magnet, and they upon the coils of wire surrounding them, and the current that was maintained in them by a galvanic battery, thus causing electrical waves in the circuit corresponding to the sound-waves

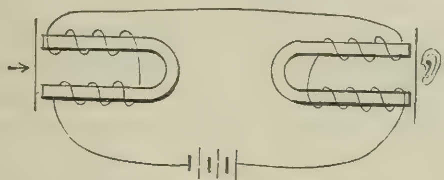


FIG. 5.

which produced them. The receiver was another electro-magnet similar to the first, but so mounted that the vibrations set up there should reach the ear advantageously. So far as the action at the receiver was concerned, it was similar in all respects to the action in Reis's receiver, nevertheless the whole is deserving the distinction of a separate system, for the receiver now became a transmitter, and thus it had an entirely new function in addition to the old one. *The really new thing about it was the transmitter*, which acted by setting up electro-motive forces in the circuit, which reacted upon the electro-motive force of the battery, and therefore varied the strength of current in the circuit. The successive steps

in this method are: Sound vibrations in air causing forced vibrations in the armature of the magnet, varying the strength of the magnetic field. The varying field reacts upon the coil of the electro-magnet, and the current of electricity present in it, setting electro-motive forces of a vibratory kind, now in this direction and now in that, according to whether the armature moved towards or away from the poles. The action is one of successive transformations of energy, the source of all the changing electro-motive forces being the energy of the sound vibrations themselves, and therefore quite unlike the Reis transmitter, which is simply a controller of the electric energy which is provided by a separate source.

In the Reis transmitter, the strength of the current is varied by mechanical means directly, while in Bell's transmitter the current is varied by magnetic means directly. The contrast is still stronger, for on the one hand the changing currents are really vibratory, to and fro in direction, while in the other the currents are all in one direction, only varying in strength. The one produces its effects by *changing the direction* of its currents, the other by *varying* the strength of a continuous current.

At the receiver, the succession of transformations is similar in each. The magnetic changes produced by the currents result in a varying magnetic field and a corresponding strength of attraction upon the armature, which moves in obedience and vibrates, imparting its energy to the adjacent air. As a matter of fact, the form of the electro-magnet employed for the transmitter was not the same as that used for a receiver. At the Centennial exhibition of the telephone, the receiver was a cylindrical electro-magnet, the coil being within the cylinder, the armature being a disc that fitted like a cover upon one end of it. This receiver was given to Sir William Thomson, who carried it home with him. During transportation, the armature got bent up to an angle of forty or fifty degrees from its proper position facing the poles. Sir William testified in a London Court, where he showed the receiver with the armature still bent out of place, that he had endeavored to make it talk after his return home, but had not succeeded, and he could not remember but that the armature was intended to be bent up as he found it on unpacking, so the man who made it was called up to testify what the intention was. I think that anyone less eminent than Sir William, who had been called as an expert, and who

should give such testimony as that, would be at once ruled out as incompetent.

In the same year, 1876, I proposed to employ permanent magnets for both receiver and transmitter, so as to dispense with a battery, and have each instrument of the same form. This was

FIG. 6.

before I knew anything as to the instruments that Bell had employed, and the first one made was with a straight bar magnet with the coil wound over only one end. This kind was soon found to be much more efficient than the electro-magnet and battery, and was adopted to the exclusion of the other. Considered as a system, however, it differs from Bell's only in this, that in the latter, the generated currents modified the current permanently in the circuit, while in mine the generated currents were the only ones in the circuit. Several electricians have stated that the two are identical, and that the only object of employing a battery was to keep the magnets magnetized, in spite of the well-enough known fact that a magnet may be made stronger by permanent magnetism than by a current on a line of any considerable external resistance, without using an inordinate battery. Somehow I had, for twenty years, the idea of the reciprocal action of magneto-electric devices. I had tried, in 1855, to make one magneto machine run another one, and, failing to do it, wrote to the editor of the *Scientific American* to know why it didn't work. The response was one of two or three lines in the column to correspondents, which answer I have forgotten, for I haven't seen the number since that time. It was marked A. E. D., Mo., where I was living at the time. Also, in 1864, I proposed a similar plan for a telegraph, the sender and receiver to be alike, and with similar functions. I mention these in justice to myself and in order to point out that there was nothing that was new to me in such combination of actions.

The system used at present in *legal telephony* consists of a transmitter of the Reis pattern, and differing from it only in the substitution of hard carbon where Reis used platinum, while for a

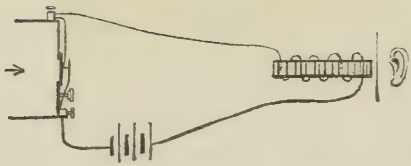


Fig. 7.

receiver is used my straight-bar permanent magnet telephone of 1876. It is Reis's system plus a permanent magnet.

BERLINER'S SYSTEM.

Berliner proposed a still more novel plan for a speaking telephone, because it involved principles unlike any of the others. His system consisted of a transmitter similar to the Reis's in prin-

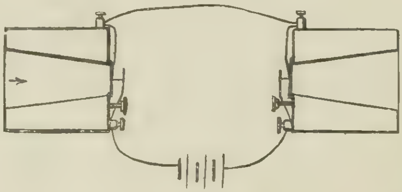


Fig. 8.

ciple, and his receiver was a duplicate of the transmitter. The two similar instruments were to be put in circuit with a suitable battery, when an electric current would traverse the line. Talking to the transmitter would vary the strength of the current, and this varying current would vary the temperature of the electrodes at the receiving instrument enough to develop there what may be called a modified Travellian effect, and produce a sound, the character of which would depend upon the varying rate of the electrical energy spent at the terminals. The receiver could then be used as a transmitter, so that, like the Bell system, each instrument had a double function. The Berliner receiver depended upon the convertability of electricity into heat, the latter at once doing work in moving the diaphragm. This was a highly ingenious plan, and is a system by itself, as much so as any I could name. The same principle has been varied somewhat and improved upon by others. I, myself, in 1878, used the heating effect of the current in a short wire to work a receiver.

Preece, in 1880 or 1881, likewise described some experiments of the same sort; while Cross has lately obtained surprisingly

good results by using a platinum wire about six inches long, fixed to the middle of the diaphragm, and a current strong enough to keep the wire red hot. He described the effect to be such that the talking could be heard several inches from the receiver. In my opinion, the transformations of energy are the same in these cases, and I therefore include them under the head of Berliner's system.

EDISON'S SYSTEM.

Ten or twelve years ago, Edison discovered that electricity was competent to lessen the friction between two surfaces, and, at first, adapted the discovery to a telegraphic receiver, and he gave the name Motograph to it. Later, he invented a telephonic transmitter, in which the current traversed a mass of lampblack, fastened between a solid back and a diaphragm, against which sound-waves could impinge. The vibrations of the diaphragm changed the conductivity of the parts and so varied the current. It is a variable resistance transmitter, in which lampblack takes the place of the platinum in Reis's transmitter. It was impossible, on account of the mechanical structure, that there could occur a break in the current in Edison's transmitter, and the changes in resistance were sufficiently great to make it excellent for its purpose. Edison then adapted his motograph to telephonic purposes, calling the modification a motophone, when he then pos-

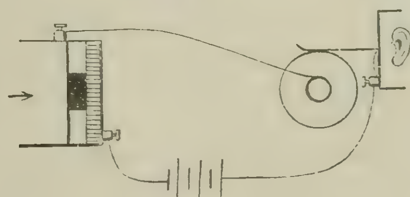


FIG. 9.

sessed a telephonic system which, for loudness of performance, leaves nothing to be desired. It embodied mechanical details in the transmitter that vastly increased its efficiency, and in the receiver there were transformations electrical, chemical and mechanical, such as had not been even known until his discovery. I am very strongly of the opinion that Edison's system is one quite distinct from any other, being radically different from anything found in Reis, or Gray, or Bell.

DOLBEAR'S SYSTEM, NO. 1.

In 1878, I devised what I called a battery transmitter, in which one of the battery plates was so mounted that the sound-waves could impinge upon it and cause it to vibrate. In fact, the plate was used for the double function of a battery element and an acoustic diaphragm, the other element of the battery, zinc, being thick and rigid. The cell was thin and small, holding but about a tablespoonful of dilute acid. When this cell was spoken to, the vibrations of the plate were sufficient to give the proper characteristics to the current which the cell itself provided, and speech was rendered in the ordinary receiver with distinctness nearly "sufficient

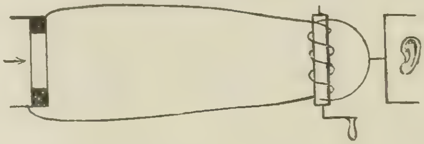


FIG. 10.

for every one." I also invented a new receiver combining the attraction of a magnet, and the varying friction produced by the varying magnetism. An electro-magnet made with a core which could be rotated on its axis within its coil had resting upon its two poles the two ends of a curved armature, the middle point to which was fastened to the middle of a diaphragm. When a current of electricity traversed the coil, the magnet attracted the armature, holding it snug against the round sides. When now the core was rotated, the adhesion caused the middle of the plate to be bent in or out, as the turning was one way or the other. If the current varied in strength, the magnet varied in strength, the adhesion varied with it, and the armature was thrown into vibrations that corresponded with the current charges, and so speech could be rendered with it. In this it is the varying friction caused by magnetic changes which is the cause of the sounds, not magnetic induction as in Reis, or chemical dissociation as in Edison's, while the transmitter had the double function of both battery and transmitter, and, therefore, in accordance with my method of distinctions, I rightfully call this a system.

DOLBEAR'S SYSTEM, NO. 2.

I once had a receiver so made as to permit a current of electricity to pass between two plates with a few drops of ammonium

chloride between them in the expectation that the decomposition effected by the current would result in gaseous products which would move the plates. I found the result I expected, and had a receiver still different in principle from any I have described, in as much as the dissociative chemical relations of the electricity was the immediate cause of the sound vibrations. At one time, while experimenting with this the liquid leaked from between the plates,

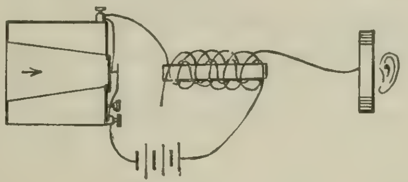


FIG. 11.

when I found I still heard the talking plainly. This new phenomenon I at once began to work out towards still better results until the receiver assumed its present form. For a transmitter, I found it necessary to use the high electro-motive force which I could only get from an induction coil. In as much as the receiver consisted of two plates as perfectly insulated from each other as it was possible to make them both by a thin layer of air and by thick varnishing, the resistance was practically infinite, and no current could traverse it; therefore a transmitter such as could only vary a current which must be maintained, was out of the question. An induction coil is an essential part of the apparatus. The complete transmitter consists of the variable resistant transmitter of the plan of Reis, hard carbon being used where Reis used platinum, combined with an induction coil of high resistance, 3,000 ohms or more, the terminals of this coil connected with the two plates of the receiver by the ordinary line wire. The structure of the receiver is such as to constitute it an air condenser, but in addition to that the varnishing upon the plates plays a very important part, an essential part in its commercial working, for it adds to the capacity of the condenser in two ways: (1.) As an ordinary dielectric, and (2.) in its absorptive property by which it becomes electrified, retaining its charge. It is then like a charged electroscope or electrometer, and is much more sensitive than when the plates are simply metallic and incapable of such electric action. In operation this system is radically different from the others, for (1.) it is not operated by a current.

The opposed plates are oppositely charged, and therefore attract each other. One of them is free to move slightly towards the other at its middle point, the strength of the attraction determining the amount of movement, but no current traverses the receiver for its resistance is measured by thousands of megohms and ohms' law has no application to it. (2.) The electrical condition of the line is entirely different from that in the other lines, for as no electricity can flow through it, the line itself becomes a charged body, and any electrical changes taking place in it are of the nature of electro-static phenomena. In the magneto telephone the electricity goes uninterruptedly through the coil to the ground beyond. In the static telephone it comes to an impassible barrier and it accumulates there, it piles up, so to speak, as the tide does against the shore. The line, therefore, may have its electrical condition likened to an ocean tide and a continuous change of level, while the magneto line may be likened to an unobstructed river with variable quantities of water flowing. Prof. Cross who has made measurements of the current strength employed in telephones with various transmitters, reports that there was no measurable current in my line, which is just what I have maintained from the outset must be the case. But there have been some electricians who have declared that so far as the line was concerned there were currents in it just the same as in the common telephone lines. (3.) High electro-motive force is another essential condition. A battery and a transmitter, however good for magneto purposes, will not work my receiver, for it is the function of the transmitter to vary the current, and if there be no current evidently there can be nothing to vary.

As both transmitter and receiver are necessarily unlike any of the others, and as the transferring line is in a different electrical condition, and the character of the transformations of energy not to be found in the others, it is a system by itself.

FIG. 12

If two receivers be placed in same circuit uncharged, if one

attempts to use the arrangement for the transmission of speech he will fail, for merely vibrating one plate near another will not generate an electrical phenomenon, but if the line be charged in any way, one may then use each instrument as transmitter or receiver. In this way I have worked successfully over a half mile of line with the most ordinary insulation.

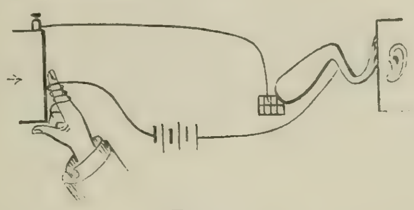


FIG. 13.

(4.) In 1878 I found that if an electric circuit was completed through the finger in contact with the bottom of a tin cup, the current on the line would be varied by the change in pressure produced by sound vibrations in the cup, so that it was a variable resistance transmittter. With a dozen gravity cells and the end of the finger moistened it is a tolerably efficient transmitter. The receiver with which I have represented this transmitter in circuit is an ideal receiver which I have threatened to make every summer for six or eight years, but have never done it. Ever since Galvani's experiment with the frog's leg that has been a standard experiment, yet I confess I never witnessed the phenomenon. It is said that the properly prepared leg of a frog is a particularly delicate electroscope, and that it only requires the contact of a piece of zinc and copper to throw the leg into spasms. I therefore proposed to connect such a leg with the plate of a telephone, completing the circuit through the leg, a battery and a transmitter, expecting that the changing currents would cause corresponding muscular movements of the frog's leg which would be communicated to the plate, in which case the diagram represents still another system.

BREGUET SYSTEM.

There is but one other complete system that I chance to know of, and that is Breguet's. Lippmann made the discovery that the surface of mercury was visibly deformed by a current of electricity upon it from the point, and Breguet reduced this to telephonic purposes. Transmitter and receiver are both alike and have similar

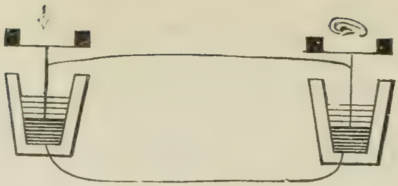


FIG. 14.

functions. A glass vessel contains some mercury with some acidulated water upon it. A small glass tube drawn to a point but not closed, is also filled with mercury and properly supported above, so that the point of the tube should be quite near the surface of the mercury. The mercury in both cup and tube must be provided with external metallic connections that an electric circuit may be completed. When these two are connected thus, any motion of either tube towards or away from the surface will be followed by a corresponding motion of the other.

There are several telephone inventions of importance, and some of them of the highest, that are in the nature of improvements. Transmitters and receivers have both been made more efficient by their use, while some have only a scientific and theoretical interest. A few of these I shall notice.

Among transmitters embodying difference in principle I would name the thermo-electric-pile. In 1873 I described at the Portland meeting of the American Association for the Advancement of Science, an experiment I had made "On the Convertability of Sound into Electricity," in which the vibration of a tuning fork upon the face of a thermo-pile had developed electricity. At the time the criticism on the paper was that the vibration resulted in heat, which was the cause of the phenomenon.

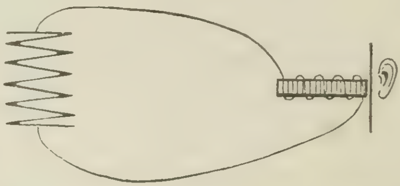


FIG. 15.

As soon as the magneto telephone was available for the test I coupled it in circuit with a thermo-pile and applied the tuning fork as before, and at once heard the pitch of the fork at the

receiver, and that, too, at the distance of half a mile from the thermo-pile. I have also heard the voice, but only very weakly, with a thermo transmitter. The electro-motive forces are at best but about ·0001 of a volt, and with such nothing much can be expected. As contrasted with such weak currents an electric arc, half an inch long, is at the other extreme.

As the arc is exceedingly sensitive to air currents, and as an arc may be blown out with the breath, it occurred to me that possibly the changes in density in air vibrations made to go through an arc would vary the current strength enough to enable

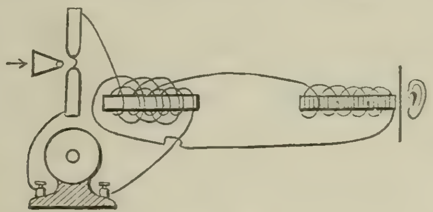


FIG. 16.

sounds to be reproduced by it. The sounds were directed to the arc by a speaking tube, every word spoken driving the sparks two or three inches away from the arc. The current was passed through the primary wire of a large induction coil that could not be injured by such a current of fifteen or twenty ampères. The terminals of the secondary connected alternately with the magneto and the static receivers. Only the faintest show of a sound could be heard. I did, however, hear some sounds, but not speech. Whistling was plainest.

I discovered one thing of interest and of some importance, too, as bearing upon future improvements in transmitters; that is, that the most sudden break of such a current produced an hundred times less sonorous effect in the receiving telephone than the break from a single Leclanché cell would give. The explanation probable is that it is impossible to produce a sudden enough break to effect the telephone, so that the ear could perceive it. Not that the ordinary effect of magnetization and demagnetization are not perceived, but their gradualness prevents an acoustic effect. It was not possible to get a spark of any appreciable length by the breaking of such a current, though with half a dozen bichromate cells a spark four or five inches long was easily obtained. As it has been

found by experience that an electro-motive force greater than three or four volts in the primary circuit with a Blake or other transmitter of that kind was not so efficient as less. I take it to be explained that within the slight movable distances, to which the terminals of such transmitters are subject, the formation of an arc across the space is detrimental to the performance, for if there be an arc the current is not varied, it continues right on with no considerable diminution. It is, therefore, necessary to use a lower electro-motive force, and that from two Leclanché cells, say three volts, is as much as can ever be employed with such transmitters.

Elisha Gray discovered a curious electro-physiological phenomenon a good many years ago, namely, that when vibratory high tension currents passed through a finger contact upon a movable metallic surface that there was an apparent increased adhesion, and the metal gave out a sound which was the pitch of the interruption of the circuit. This he modified into a telephonic receiver. The phenomenon is curious when compared with that of the motophone of Edison, for in the latter the friction is lessened by the current, while in the former it is increased.

Lastly, there are three telephonic receivers, which have nothing but novelty to recommend them, but I thought you might like to know of them.

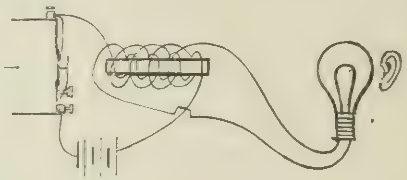


FIG. 17.

(1.) An incandescent electric lamp of the ordinary sort makes a speech receiver. The current needs to be a strong one, and it performs better when the current is sufficient to heat the filament to low redness. I suppose it is to be explained by what I have described under the head of Berliner's system.

(2.) Crooke's tubes may be similarly employed, only a high resistance induction coil is needed. By using one in which the gaseous impacts are against the side of the tube, or bulb, and that held against the ear, one may hear the spoken words.

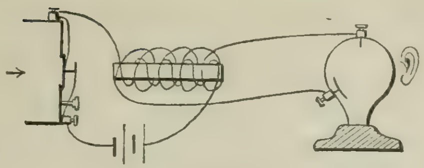


FIG. 18.

(3.) A Leyden jar of the ordinary pattern held, one hand grasping the outer coating while the knob is placed in the ear, the two coatings being the terminals of a secondary from almost any kind of a transmitter.

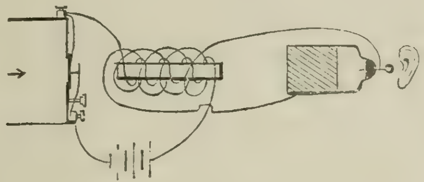


FIG. 19.

It was Hughes, of England, who discovered the great sensitivity of hard carbon and pointed out its adaptability to telephonic purposes. A discovery of such importance, that if he had seen fit to patent, as he might have done, he would have practically controlled the telephone for commercial purposes. The Royal Society of Great Britain has just honored him for this among other distinctions. It has been claimed by those who own the right to the use of plumbago and lampblack for such uses that they also own hard carbon of any sort, but they are no more to be compared than peet and anthracite.

The properties of a body are not the properties of the atoms of the body, but depend upon the molecular constitution and arrangement of the body. It is the atom that is named carbon. It is the molecular properties that are wanted, and the molecular properties are not the same in lampblack and gas coke. If one should discover that starch could be used for a certain useful purpose, and afterwards some one should discover that cotton would answer very much better, and if the first should then claim the cotton because he first described an amylose for the purpose, the cases would be similar. Yet I heard Sir William Thomson say that it required but an infinitesimal amount of invention to substitute gas

coke for lampblack, and we all know what infinitesimal means to him.

The Blake transmitter consists simply in the adoption of Hughes' hard carbon for the platinum in Reis's transmitter. It makes it much more efficient, but does not change its mode of operation nor vary the mechanical relations.

Hunning, an English clergyman, has made a very useful transmitter by employing granulated hard carbon, arranged mechanically in the circuit as Edison arranged his carbon button, and with this transmitter the best long line work has been done.

In conclusion, I do not pretend to say who was the first inventor of an art of telephony, but I think I have made it plain that there are several arts of telephony that are complete in themselves, just as there are several arts of picture painting. One man paints with a brush, another with a roller and a press. When the pictures are done, no one can tell, by inspection, which way either was made, hence it is improper to speak of *the* art of picture making. Leaving out all that was done before 1876, I submit that the work of that year ought not to control systems that have been invented and discovered in their entirety since that time, and have almost nothing in common with it. I protest against it in the name of law which has been misjudged; I protest against it in the name of equity which has been scandalized; and I protest against it in the name of science, whose eyes are not bandaged as are the eyes of justice, herself a judge, the court of highest appeal, and who writes after every signature to a judgment in her court, *competent* or *incompetent*.

GENESIS OF CHOLERA.—In a recent sitting of the French Academy of Medicine, Professor Peter expressed the opinion that European and Indian cholera differ only by the relative morbific intensity of the producing causes. The two forms may arise spontaneously, either in Europe or in India, being engendered in either case by volatile ptomaines produced by organic putrefaction. M. Gustave Le Bon reports some interesting observations, made during his visits to India, which strikingly corroborate these views. The cholera in India is confined almost exclusively to the Hindoo population. Even in the great cities all the English live in cantonments, which are reserved for their exclusive use, at some kilometres from the towns. The hygienic arrangements are very complete; neatness is pushed to excess, and the most scrupulous attention is paid to the origin of the water which is used. —*Comptes Rendus, Sept. 21, 1885.*

GLIMPSES OF THE INTERNATIONAL ELECTRICAL EXHIBITION.

By Professor Edwin J. Houston.

[*Concluded from Volume CXX, page 388.*]

NO. 8. REIS'S INVENTION OF THE ARTICULATING TELEPHONE.

In telephonic communications, mechanical vibrations of the transmitting diaphragm, are, through the agency of electricity, mechanically reproduced at the receiving diaphragm. The question in dispute between Reis and Bell, is, as to the nature of the electrical currents that transfer the motion from the receiving to the transmitting end of the circuit.

Can an electrical current in which makes and breaks occur successfully transmit articulate speech? This question it will be perceived is vital to the interests of Bell, since, unless he can maintain the absolute necessity for his undulatory current, the extent of his alleged invention is very considerably decreased. Instead of having created a new genus of apparatus, he has merely produced a modification of what has already existed. Apart, therefore, from the question of what Reis really intended by his makes and breaks let us carefully examine this question.

Scientific men have by no means given unqualified assent to the necessity for the employment of an undulatory current in the telephonic transmission of articulate speech. On the contrary many of the ablest physicists and electricians have expressed grave doubts in the matter. I will give a few quotations to this effect, taken from testimony in some of the Bell Telephone suits for alleged infringement. Dr. Wm. F. Channing testified in one of these suits as follows; viz.,

Q. "And don't you also know or believe that the electric transmission of speech depends on the precise mode of operation stated in that question?"

A. "I do not. It is the merest assumption that no other method exists for the transmission of articulate sounds than what is called the undulatory current. The vibrations of sound which enter

into articulation are not undulatory (in the form usually represented by graphic curves) In their ultimate analysis they are to-and-fro vibrations in a straight line.

They do not resemble the waves of the ocean nor the undulatory curves which for convenience are made to represent the form of simple or compound sounds in their relations to time. We have no evidence whatsoever that any articulate sound cannot be reproduced in the telephone by as many separate electrical impulses as there are separate sound vibrations, the electrical impulses corresponding precisely in number, intensity and combination with those of sound."

Again, speaking of certain tracings, or records, obtained by means of a machine devised by Prof. E. W. Blake, for describing Compound Harmonic Curves, he says,

"The characteristic to which I wish to draw attention in all these records, is that the effect of compound sounds, such as enter into articulation, is to produce a very few abrupt and marked changes in the motion of the telephone diaphragm, and of its equivalent in the phonograph. I wish also to draw attention to the fact that these changes in the motion of the diaphragm, which are the principal characteristics of its articulatory action, are often or mainly arrests or reversals of its motion. An arrest of the motion of the diaphragm means an arrest of the current. A reversal of the motion of the diaphragm, means an interruption and reversal of the electric current."

"Interpreting thus these graphic records, I have no hesitation in saying that the elements of articulation which are actually influential on the plate, and which ever actually reach the distant receiving end of the line, may consist entirely of makes and breaks of different order, duration, and force."

Again in the same answer

"I do not believe that the electric undulations are ever similar in form in any accurate sense to the vibrations of the air accompanying the sounds of the voice made in a transmitter. The method of electric transmission is complex and artificial, and for reasons already stated differs widely from the air vibrations which originate it."

Prof. Cyrus F. Brackett testifies in one of the above suits as follows:

Q. "Do you know it to be true that a simple sound represented by a sinusoidal curve cannot produce an electrical undulation by the intervention of an inductive action which can be represented graphically without error by the same sinusoidal curve; and if you know that to be true when and how did you make that discovery?"

A. "I am as sure as I am of most facts on which we place implicit confidence that while such undulations may be graphically represented with approximate similarity, they cannot so be represented without error; and as I have been asked when I made that discovery, I may answer generally that the results in telephonic transmission, as a matter of fact, never do, to the best of my knowledge and belief, exactly correspond with and copy the sounds delivered to the transmitter. Accurate date as to when I made this discovery I cannot give. It is notoriouly a subject of discussion by mathematicians and experimental physicists to determine the laws which govern the changes found to exist between the spoken and received words of a telephone. My knowledge is partly derived from experience and is partly theoretical."

Again the same witness,

Q. "Assume it to be true that the circuit is broken and closed at each vibration, is it your opinion that such an apparatus as that combined with the best receiver now in use, and without any other apparatus, except the battery and wires, can transmit articulate speech practically."

A. "I have no question whatever that it is entirely possible on the hypothesis in the question to so transmit articulate speech, and I will give my reasons in part: When a circuit is closed, as that term is commonly used, it by no means follows and is not true that the current suddenly reaches its maximum, and it is not true that when the circuit is interrupted, as assumed in the question, that the current suddenly and immediately ceases along the whole line. Several conditions will determine its establishment and cessation, among which may be mentioned the length and resistance of the line, its static induction, its mutual induction arising from the necessary introduction of magnet in the circuit, etc. It, therefore, follows that if the making and breaking, assumed in the question, are properly timed relatively to each other that the effect at a distant point at which a telephonic receiver may be placed will be such that it will be thrown into vibration under the impulses of

the electric pulses or undulations which reach it and which may be made to be of the proper form to reproduce the words spoken in the said assumed interrupting transmitter."

Again in answer to another interrogation the same witness testifies

"It is still (Mar. 15, 1884) an open question, whether that class of instruments known, popularly as circuit breakers, of which Reis, McDonough, Hughes' microphone, Blake transmitter, etc., are examples, operate by making and breaking the circuit, so as actually for minute intervals of time to thereby reduce the current to a minimum, or whether they act through continuous contact by varying pressure to alter the resistance in the line in substantial accordance with the vibrations constituting sound as employed in articulate speech."

So also Prof. C. A. Young, deposes as follows:

Q. "Did you mean to say that in your opinion the microphone operates by making and breaking the circuit, and not by varying the strength of current which is maintained through the joint during the operation of transmission?

A. "I intended to say that in my opinion it is not yet (Feb. 13th, 1884) certain in what precise manner the microphone produces variations in the strength of the current at the receiving end, and that in my opinion the theory that it is done by minute makes and breaks is not demonstrated to be false."

Again. *Q.* "In your opinion, does the intelligible transmission of speech require that the motions of the receiver-membrane or diaphragm should be a strict copy of the motions of the air in contact with the transmitter, and if not, why not?

A. "It does not. Undoubtedly speech can be transmitted by such a strict copying—but such a copying is by no means necessary. The characteristics of a spoken word which render it intelligible as such, do not consist either in the absolute pitch of the sounds made, nor even in the quality of the sound, as that term is commonly understood. A fact, which is evident from this, that a given word spoken by a woman and by a man will differ in both these respects."

These opinions could be readily multiplied but those given above will suffice for the present.

With the above and similar opinions Mr. Bell is at variance.

Simple sounds, in his opinion, may be transmitted by means of complete makes and breaks in the electrical currents, but complex sounds, even such as simple chords, cannot be readily so transmitted. Let us examine carefully the argument as given in his U. S. letters patent and elsewhere, by which he endeavors to prove this assertion. He is discussing, in his patent of Mar. 7, 1876, the attempt to simultaneously transmit, by what he terms intermittent currents, two sounds the interval between which is that of a major third, or 4 to 5; he speaks as follows; viz., "Now, when the intermittent current is used, the circuit is made and broken four times, by one transmitting instrument, in the same time that five makes and breaks are caused by the other. *A*, and *B*, *Figs. 1*, *2*, and *3*, (*our Fig. 17*)

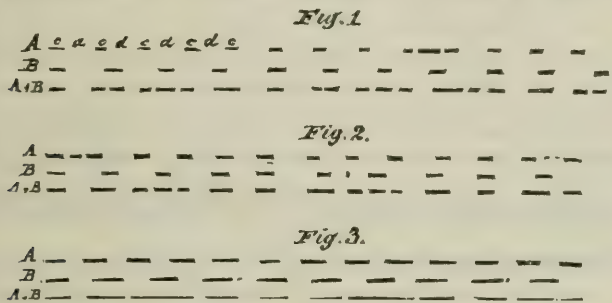


FIG. 17. Bell's ideal representation of effects produced by the simultaneous transmission of pulsatory currents of different rates.

represent the intermittent currents, produced; four impulses of *B*, being made in the same time as five impulses of *A*; *c*, *c*, *c*, etc., show where and for how long the circuit is made, and *d*, *d*, *d*, etc., indicate the duration of the breaks of the circuit. The line *A* and *B*, shows the total effect upon the current when the transmitting instruments for *A*, and *B*, are caused simultaneously to make and break the same circuit. The resultant effect depends very much upon the duration of the make relatively to the break. In *Fig. 1*, the ratio is as 1 to 4, in *Fig. 2*, as 1 to 2; and in *Fig. 3*, the makes and breaks are of equal duration. *The combined effect, A, and B, Fig. 3, is very nearly equivalent to a continuous current.* (*Our italics.*)

"When many transmitting instruments of different rates of vibration are simultaneously making and breaking the same circuit, the current upon the main lines becomes for all practical purposes continuous."

The idea intended to be conveyed is that when an endeavor is made to simultaneously transmit several rates of vibration by intermittent currents, the intervals that exist between the successive makes of any one of the tones, during which it is assumed that no current passes, will be occupied by some or all of the intervals that exist between the breaks of the other tones, so that a continuous current will result in which the characteristics of its separate components cannot be detected.

Would this be the case? We think it can be shown that Mr. Bell has thus introduced into his specification graver errors than those imputed to Mr. Reis in the interpretation often put on his description of makes and breaks.

Before discussing this, however, let us enquire more fully into the artificial distinctions which Mr. Bell has endeavored to sharply draw as to the different kinds of currents possible in telephony.

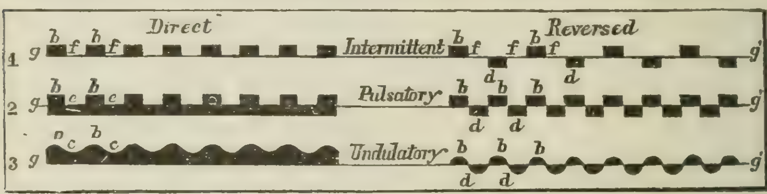


FIG. 18. Bell's classification of Electrical Currents.

Fig. 18, is taken from a chart used by Bell in a lecture delivered before the Society of Telegraph Engineers, in London, Eng., on Oct. 31, 1877. This chart recognizes three primary varieties of telephonic currents, viz., the intermittent, the pulsatory and the undulatory.

The intermittent current is one which is alternately present and absent from the line.

The pulsatory current is one which "results from sudden or instantaneous changes in the intensity of a continuous current."

The undulatory current, is "one in which the intensity varies in a manner proportional to the velocity of the motion of a particle of air during the production of a sound."

Of each of these primary currents there are two varieties, viz., the direct and the reversed.

In speaking in a public lecture, of the effects produced by the simultaneous transmission of several notes of different pitch by means of intermittent currents, he calls attention to the diagram

shown in *Fig. 19*, which with *Fig. 18*, is taken from Prescott's work on the Speaking Telephone.

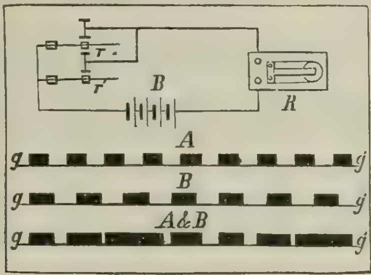


FIG. 19. Simultaneous Transmission of Several Intermittent Electrical Currents.

In this figure as before, the interval between the two tones is that of a note and its major third. The lines *A*, and *B*, are intended to represent the currents produced by two tuning forks *r*, and *r′*, tuned to the above interval, and vibrated so as to simultaneously open and close the circuit of the battery *B*. The line *A* and *B*, is supposed to represent the effect produced on the circuit by the simultaneous presence of both the notes, and is intended to show that the result is still an intermittent current with, however, some of the intervals extinguished.

In the case represented in this figure the intervals in which there is supposed to be no current are assumed to be equal to those in which the current exists. Both in the patent already referred to, and in his lecture, Mr. Bell has represented a state of things that it is difficult to conceive of as ever actually existing in practice. Certainly he can not realize it by the use of the means he describes. We refer to his representation of the current as suddenly beginning and as suddenly ceasing to flow. With the arrangement of parts as shown in *Fig. 19*, and indeed with the actual condition of all telephonic circuits, such a condition could never be attained in practice. In even comparatively short lines, some time would be required to charge the line and thus establish the current, and some time would undoubtedly be required to discharge the line, and thus cause the current to cease, while in large lines the intervals of charge and discharge would necessarily be prolonged. So too, the effect produced by the induction of the current on itself, both on making and closing the circuit, would beyond question make the representations

of the abrupt beginnings and endings of the currents pictured by Mr. Bell, as false and misleading. The inverse current on closing, being in the opposite direction to the direct current, might make the starting of the current more sudden by opposing it, while the direct current on breaking would tend to prolong it. The true representative then would not be the rectangular spaces as figured in Bell's patent and lecture, but the edges of the rectangles should be cut off rounded, thus making them approximate more closely to half circles, or circular segments.

Now let the makes and breaks follow one another more rapidly; then the adjacent semi-circles would touch one another and the line would never be quite free from an effective current. It would, however, be subject to variations in strength, which Mr. Bell conceives may take place suddenly or instantaneously, thus producing the pulsatory current, or rather, as we have shown, necessarily taking place gradually, and thus producing the undulatory current.

The distinctions therefore drawn by Mr. Bell between the intermittent, pulsatory, and undulatory currents appear in actual practice to be rather differences of degree than of kind, and the assertions so frequently made that mere makes and breaks cannot possibly produce undulatory currents in a line, are apparently groundless.

But Mr. Bell asserts that the necessary effect of simultaneously throwing on the line a number of variously timed intermittent currents is to produce a uniform or practically constant current, in which the peculiarities of its separate components are necessarily lost. Let us enquire carefully into the truth of his assertions, since if he is correct then the statement we have made in the preceding paragraph is inaccurate

Mr Bell's manifest error in this regard has been ably pointed out by Locht-Labye, in a recent number of *La Lumière Electrique*, who suggests, referring to Mr. Bell's lecture, that if a single battery be employed for each interrupter of the current then the statement of the uniformity of the resulting current is entirely erroneous and based on a failure to properly consider the conditions of the problem. For, it is evident, that taking the case of a note and its major third as represented in *Fig. 19*, if each interrupter had its separate battery, there would necessarily be times during which the interrupters would be jointly throwing their currents into the line, thus producing a current whose intensity would at such moments

be the sum of the two: there could not then possibly result the hypothetical uniform current so positively stated by Bell as necessarily ensuing.

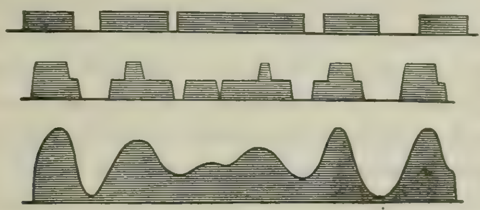


FIG. 20. Effect of Simultaneous Transmission of a Note and its Major Third.

In *Fig. 20*, which is collated from the *Scientific American Supplement* for May 23, 1885, the upper drawing shows the effect which Bell asserts would be produced on a telegraphic line from the simultaneous transmission of a note and its major third by the use of an intermittent current. The lower line, Bell's representation of the effect produced by the simultaneous transmission of the same notes by means of undulatory currents, while the middle line represents the effect which would probably be produced by the simultaneous transmission of these notes by intermittent currents when each interrupter was furnished with a single battery. The evident similarity of the second line with the third will be apparent.

If currents represented by the middle line in the above figure can be produced by the simultaneous transmission of but two different rates of intermittent currents, what must be there sult when more than two are thus transmitted? Must not the result be the practical production of the undulatory current?

Examining again, therefore, in this light, Bell's classification of currents as shown in *Fig. 17*, is it not evident that the direct intermittent current must become in some cases truly undulatory, and that the direct pulsatory current cannot fail in actual practice to be invariably undulatory? And if this be true of the direct currents, must it not be still more apparent in the case of the reversed currents?

We repeat, therefore, that the differences pointed out by Mr. Bell between the intermittent, pulsatory, and undulatory currents, are in practice rather those of degree than of kind. We therefore conclude that it is not impossible to transmit articulate speech

through the proper succession of discontinuous currents of sufficiently short duration.

It has been pointed out in some of our previous articles that in the great majority of cases in actual practice the telephone circuit employs the induction coil, the transmitter being in the circuit of the primary and a battery, while the line wire is connected with the secondary of the coil. Now it is well known that the use of an induction coil, so far from decreasing the intensity and clearness of the transmitted speech, actually increases both. This could hardly be the case if the currents sent into the primary wire by the transmitter had the gradual variations in intensity, that the undulatory current would seem to necessitate. They must, therefore, have sudden variations.

Commenting on Bell's assertion that for any sound to be transmitted telephonically "electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sounds," must be thrown into the line, Locht-Labye in the article before alluded to very neatly says:

"If Prof. Bell's theoretic ideas were admissible in a general way, and if an application were made of them in the other departments of physics, it would be necessary to adopt this formula: A physical phenomenon, during its diffusion through several media, and by different agents, must preserve all its peculiar characters without alteration in duration or form. This is an absolute negative of the law of the transformation and *reversibility* of phenomena recognized in a general way in physics. Can this formula, which, applied to the different departments of physics and chemistry, would constitute a scientific heresy, be the expression of truth in telephony? Such derogation with so general a rule would at least be surprising!"

In conclusion he speaks as follows:

"The abrogation of the law recognized in physics does not, as Prof. Bell has supposed, exist."

"Telephonic transmission by electricity obeys the general law of the reversibility of the phenomena of nature, which, after a series of successive transformations, in which their peculiar characters and phases may be absolutely modified, reappear with all their constituent qualities."

"The original sound is produced by mechanical action. In its

propagation through the air, and then through the solid parts of the telephone, the mechanical motions are effected with the qualities proper to each of these media. Mechanical motion is afterward partially converted into magnetic or electric motion of several natures, though one or several inductions, in order to become again magnetic and then mechanical, with phases in the receiving telephone contrary to those it had in the transmitter.

We will now discuss a difficulty that perhaps with some has stood in the way of an admission of the possibility of mere intermittent or pulsatory electrical currents transmitting articulate speech. We refer to the fact that speech can be transmitted with the use of the magneto-electric telephone. Now it is probably argued that by the use of the magnetic inductions produced by the movements of the diaphragm by the sound waves that undulatory currents are thereby set up in the coils surrounding the magnets: or, as Bell would say, "an undulatory current of electricity" "the undulations of which correspond, in rapidity of succession to the vibrations of the magnet, in polarity to the direction of its motion, and in intensity to the amplitude of its vibration." It must not be forgotten, however, that though such currents may theoretically be produced, in reality, owing to the time required to charge a long line, and the impossibility of instantaneously or suddenly changing the direction of a current already established, as well as to the retarding effects of induction of the current on itself, or on neighboring wires, or of neighboring wires on the current, it may be regarded as scarcely probable that true undulatory currents in the sense described by Bell are transmitted over the line even in such cases. It is because these currents have generally been regarded as undulatory, and are known to transmit speech, that some have doubted the ability of any others to transmit speech.

Admitting, for sake of argument, the true undulatory character of the magneto-electric telephone currents, the objection against the possibility of intermittent or pulsatory currents transmitting speech is based, it appears to us, as a misconception of what actually occurs in the undulatory field in close proximity to a speaker, and in the undulatory field near the ear of an even moderately distant hearer. It has been assumed that all the peculiarities of the field at the transmitting end, must necessarily be reproduced at

the receiving end in order that intelligible articulate speech may be transmitted. Now such is not even generally the case. The finer vibrations or overtones, that constitute what is recognized as the quality of a speaker's voice, may be gradually dropped out of the sound waves without at all interfering with the intelligible reception of the speech. Indeed, were this not true it would be impossible for two persons to converse at even inconsiderable distances apart, since, as is well known, the amplitude and the energy of the overtones of all compound sounds are exceedingly small so that the overtones fade off very rapidly from the point of origin of the original sound. Mayer has shown that the finer overtones are so rapidly extinguished that at no very considerable distance from the speaker they become too weak to be heard. The author, too, has found that in the transmission of the human voice through rods of deal, the overtones were practically extinguished at even short distances. Such extinctions do not, however, prevent the intelligible transmission of speech. Speakers can be understood even when at such considerable distances that none but the stronger vibrations are transmitted.

Articulate speech may therefore be rendered by air waves that omit some of the original components. The undulatory motions at the hearer's ear are not only not necessarily, but not even generally exact copies of those at the speaker's mouth. There is no physical reason therefore why articulate speech may not be transmitted electrically by means of suitably timed makes and breaks.

A similar analogy exists in case of the eye. The brain takes correct cognizance of a printed page, though never read before, even if an opaque body like a sheet of paper be so held as to obscure all of a single line except about one-fourth or one-fifth of the letters. Habit permits us to mentally supply the portions effaced. So too with the ear. We can supply intelligently the portions needed, and this not only in the case of detached words, or portions of conversation, but in extended discourse.

It is not impracticable, therefore, in view of these facts, and of the conditions of the establishment and discontinuance of currents in long lines of conductors, that speech may be successfully transmitted by means of intermittent currents, even when comparatively extended breaks occur in the same.

That speech actually has been transmitted by means of strictly

intermittent currents, we will deduce a few of the many experiments tried by different investigators.

The London *Electrical Review* describes an experiment in which there was interposed in the circuit of a microphone transmitter, a ribbon of paper similar to that employed in automatic telegraphy. The paper had small holes very near each other, extending longitudinally through its middle. The paper, which was placed beneath a wire brush and over a metallic drum, and moved at the rate of 1,000 words per minute. There were thus, beyond any possibility of doubt, makes and breaks introduced into the telephone circuit at the rate of several thousand per minute. When now under these circumstances, that is while the paper was in rapid motion, speech was uttered at the microphone, it was intelligently received at the receiving telephone. Speech can therefore be transmitted though makes and breaks are continually occurring in the circuit.

But can speech be transmitted by means of the currents which are thus actually made and broken? I will quote here the description given by Dr. Wm. F. Channing, of an experiment made by McDonough.

"I am able to adduce, what I will not call a proof, but an evidence, much more direct than this, that articulation may be produced by the method of an electric current actually made and broken. An instrument has been constructed and is in existence, in which what I think must be accepted as undoubted, articulation is produced by simply making and breaking the electric current. This instrument consists of a toothed-wheel rheotome of about thirty-seven inches diameter. The wheel is of iron with a brass tire. This tire has a large number of minute serrations, on which in rotation, a spring bears. The spring is connected with a single Leclanché cell, the other pole of which passes to a large electro-magnetic telephone receiver, the return wire of which is connected with the axis of the rheotome wheel. The serrations on the tire of the wheel, I understand, were planned, as regards their distance and grouping upon a careful study of a phonograph record. When this wheel was turned by hand, I heard the word "hello" proceed from the tambourine receiver. The sound of the aspirate *h*, and the *e*, and the *o*, were very good. The articulation, as good as I have often heard it in telephones, was due simply to makes and breaks of the electric current, so arranged as to effect changes in the pitch and the intensity of the sound produced in the receiver."

Other experiments have been made in this direction, but the above will suffice.

We have already pointed out that the undulatory movements of the diaphragm of the receiving telephone, though not exact copies of the undulatory movements at the transmitting diaphragm, are nevertheless undulatory in their character. Let us now briefly enquire whether properly timed makes and breaks sent over the line are capable, on theoretical grounds of producing such movements in the receiving diaphragm.

It appears to be tacitly admitted by the advocates of Bell, that although in transmitting instruments of the microphone type, partial makes and breaks may take place in the electrical contacts, yet, if the circuit is not completely broken that such a current may transmit intelligible speech, since the variations thus thrown on the continuous current passing in the line produces therein a true undulatory character. Now apart from the fact that it is by no means clear to us that such a current is not pulsatory rather than undulatory, still, since we have already pointed out, the difference between pulsatory and undulatory currents is one of degree rather than of kind, we may for sake of argument admit its undulatory character, and agree that it is so because the current is never entirely absent from the line. But according to the same argument, if a sufficiently great number of separate electrical sources were throwing their current on a continuous current they would thereby render it undulatory.

Fixing our attention now on what occurs when any current reaches the magnetizing coil surrounding the magnet at the receiving instrument, we will at once perceive that if this is a permanent magnet, as used by Reis in some of his instruments, *that the permanent magnetism of the receiving instrument plays exactly the same part as the continuous current is obliged to play in the microphone transmitter.* The varying currents passing over the line either increase or decrease the strength of such permanent magnetism and set up therein true undulatory effects. If these makes and breaks can produce undulatory effects in a continuous current, *then makes and breaks, pure and simple, passed over a telegraph line, must necessarily be able, when changed into magnetism, to similarly produce undulatory* effects in the magnetic field of the receiving instrument.

We would infer, therefore, that it should on theoretical grounds be possible to convert undulatory effects at the transmitting telephone into properly timed intermittent currents, *i. e.*, makes and breaks; to transmit them over a line and produce at the other end in the receiving diaphragm, undulatory effects that are sufficiently exact copies to correctly reproduce the speech uttered into the receiver. It is by no means clear therefore that Reis did not more accurately describe the operation of his telephone than Bell claims to have done.

In concluding the brief history we have given of Reis's invention of the articulating telephone, we have thought it advisable, as far as possible, to append the views of some of the leading scientific men in the United States concerning the position, which in their opinion, Reis occupied as regards the invention of the articulating telephone. The list is by no means exhaustive; nor has any attempt been made to obtain the opinions of those known to be adverse to Reis. It fairly shows the error of the statement that the leading scientific men of America, recognize and fully endorse the pretensions of Bell.

The following circular letter was sent, viz:

HALL OF THE FRANKLIN INSTITUTE, PHILADELPHIA, 1885.

My Dear Professor :—I purpose concluding my articles on the Reis Telephone, with a publication of the opinions, as far as I can obtain them, of some of the scientific men in the United States, as to the part taken by Reis in the invention of the articulating telephone.

Will you therefore write me at your earliest convenience, your opinion as regards the following interrogatories, viz:—

First. Please say whether or not in your opinion Reis was the inventor of the speaking telephone?

Second. Whether, if it was a speaking telephone, it worked substantially in the same way as the Bell Telephone, or not?

Third. Whether the electrical current employed in the transmission of speech was an undulatory current in the same sense as it is in the Bell Telephone, or not?

Fourth. Whether Reis ever actually succeeded in transmitting articulate speech as he claimed?

Fifth. Whether the defects in the Reis apparatus are to be attributed to his transmitters, or to a want of sensitiveness in his receivers?

Sixth. Whether the modern transmitting telephones of the variable contact type are anything more than the Reis transmitters with carbon substituted for the platinum contacts?

Thanking you in advance for your courtesy in the matter, I am,

Very respectfully,

EDWIN J. HOUSTON.

Prof. A. E. Dolbear in answer to the above kindly sent me in addition to a very full reply by himself, a number of letters received by him from scientific men, referring to the same subject, with permission to publish the same.

TUFT'S COLLEGE, COLLEGE HILL, Mass., Oct. 1885.

PROF. EDWIN J. HOUSTON:

My Dear Prof.:—I have taken great pains to learn what Reis did with his telephone and what is possible with it, and I think it possible that I have made many more experiments with it than Reis himself did. The whole interest in the present controversy centres in Reis's transmitter, as to whether it is, and was in Reis's hands, capable of so modifying an electric current, through the automatic action of sound vibrations, as to produce what is now called the undulatory current, and of transmitting articulate speech. Now the structure of Reis's transmitters is so well known that a detailed description is not needed. All of them (for he made eight or ten forms) were so made that sound vibrations of any sort should act upon a diaphragm, carrying an electrode, upon which rests with gentle pressure, either by a spring or by its own weight, another electrode, these being part of an electric circuit, the intent evidently being that the actual movements of these electrodes, when actuated by sound vibrations, should modify the strength of the current so that it should represent as nearly as possible the wave movements in the air. If Reis's apparatus was not *intended* to duplicate such air movements by changing the energy of the current by the transmitter, I can see no use for Reis's figures of compound sound waves and his extended explanations of them. Whether apparatus so made and used will so modify a current is simply a matter of fact and in no wise depends upon any one's theory of electricity, or sound, or molecular action, or of make and break of circuit. It ought not to be lost sight of, nor kept obscure, although every effort has been made to divert attention from it, that Reis's transmitter like every other kind of transmitter acts *automatically* when it works at all, and its individual vibrations cannot be controlled by any one. Whether there will be a make and break of contacts or not, depends upon the rate of vibration and the amplitude of vibration of the diaphragm. If the amplitude be great and the rate low, the electrodes will not separate, for the free one can follow the movements of the membrane. If the amplitude be small and the rate high they cannot separate; in either case there will be only a variation of pressure of the electrodes at the point of contact. So much is purely mechanical and automatic, but it needs to be said and emphasized, for, first: it is true; and second: because this was lost sight of by the courts, and has cunningly been evaded by those interested in the denial of Reis's claims to be considered as the inventor and maker of the first speaking telephone. Every one who has experimented with Reis's transmitter knows that it will transmit articulate speech, except a few, a very few, who have an interest in not knowing. I have known one such to find a convenient excuse for absence when he had good reason for thinking that by staying his expressions of opinion would have to undergo revision.

Now Reis invented a device which he called *The Telephone*. He described its structure so that others could make similar ones, and in addition he undertook to explain throughout its mode of operation, a work which it is impossible to complete even to-day with all the advance in the knowledge of electricity and mechanics. It is in his explanation of the mode of operation of the instrument that he speaks of making and breaking the current. It might fairly be asked how Reis could absolutely know that there was a make and break for every vibration supposing that it did actually occur. He could not prove it, and, as a matter of fact, it is mechanically impossible that it should make and break the circuit for every vibration for complex sounds.

Let us suppose that we are in Reis's room, where his apparatus is set up, and we ask him how it is to be used? He says to one at the transmitter "Make sounds of *any kind*, it will transmit them," and to the one at the receiver "simply listen at the receiver." The first sings and speaks, and the latter says he heard the singing and words. Ask Reis to explain how the thing is done and he talks about makes and breaks of the current at the movable contacts of the transmitter. But Reis, how do you know that it makes and breaks for every vibration when it is transmitting words? Reis didn't and couldn't know. What Reis was doing, was helping his auditors to an easy conception of the possibilities of his apparatus, and I submit that at this day his explanation is the shortest and simplest for any who are not somewhat skilled in physics. I am not saying that it is not possible to transmit speech by a make and break circuit for every vibration, because McDonough with his wheel has demonstrated that it can be done and has thus proved that Reis was right, if such a construction be put upon his words. What I am saying, is, that if Reis *intended* that his apparatus should make and break the circuit for every vibration, then he failed, for his apparatus won't do it. It works *automatically* when it works at all and does not depend upon the *intention* of the speaker to make and break for every vibration. In the Spencer case, Judge Lowell gave the famous decree that 100 years of Reis would not make a speaking telephone. The 100 years is up, however, and McDonough with his *make and break* wheel says *hello*, easily recognized by Profs. Young, and Brackett, and many others as well as by myself.

When Sir Wyville Thomson sent home from the *Challenger* his observations on *bathybius*, Prof. Huxley sought the first print to say that he was mistaken when he gave the substance its name and philosophical importance—an example which a $20,000,000 monopoly could not afford to have followed.

Again, it is admitted everywhere that there is no *mechanical distinction* between the Reis transmitter and the Blake transmitter, and that the efficiency of the latter depends upon the employment of carbon where Reis used platinum. Does any one think that Reis would have explained his device differently if he had used the substitute? or, that he would not have had a speaking telephone comparing well with any we have to-day?

It has been affirmed again and again that if Reis's transmitter will transmit now, it is because we apply knowledge to it which has been acquired since 1876. Take then a Reis transmitter that has not been touched since

1864, if such an one can be found, and connect it properly in circuit with a battery and connecting wire. If it be spoken to will it act microphonically or not? Any one having knowledge enough of the apparatus to be entitled to an opinion, who should say that it would not, would be entitled to admiration for his hardihood. If it will work microphonically it is because such action is *inherent in the mechanism* and not on account of any knowledge imported into it, and any such assumption is a fiction, warranted by nothing except the necessity for denying the right of the public to use that instrument for the purpose for which it was made. One may sing to it, may whistle or screech at it, but remember that if anyone hears a word from it the Bell Company is entitled to his head. "The law allows it and the court awards it."

But making no distinction between the description of a piece of apparatus and the explanation of its mode of operation, giving the merit of the invention to the man who properly explains it would make fine work throughout science. Let us see! When Crookes made and exhibited those wonderful tubes called *radiometers*, he explained their action as being due to the direct action of light upon the delicately-poised vanes. He *intended* that the impact of light waves should propel the vanes, and they certainly rotate as he also *intended*. Afterwards Stoney and others, better acquainted with thermo-dynamics than was Crookes, gave a more consistent interpretation of the motion, but I have yet to hear that 100 years of Crookes wouldn't make a radiometer. Is it because there was no $20,000,000 behind it? Brewster invented the kaleidoscope, but as long as he lived he explained its phenomena on the basis of the corpuscular theory of light. Brewster's claim was not denied. Was it because there was no $20,000,000 behind it?

If Daguerre explained the action of light upon his sensitive silver plate as being due to the formation of a solar salt upon it, the degrees of shade depending upon the amount formed, he was altogether wrong, but the one who explained the chemical action upon the plate, made no claim to the discovery of photography. Was it because there was no $20,000,000 behind it? Let one invent a new galvanic battery cell and describe it, telling what solids and liquids to use and their proper disposition in the cell. Let him explain that it is his *intention* that the ammonia shall combine with the zinc, and the chlorine be set free upon the carbon. The battery shows when it is set up, that that evidently was the intention, for the elements are placed in proximity and are free to *if they will*. The courts may declare that what he invented was what he explained, not what he made,—if there be $20,000,000 that wants the invention.

Grove invents a galvanic battery and describes its make-up, and explains its action on the *chemical* theory of electricity; Bunsen improved it by substituting carbon for the platinum and explains the whole on the *contact* theory of electricity, which is endorsed by Sir Wm. Thomson and many other physicists. What Grove had in mind was to produce electricity chemically, Bunsen had in mind the correct conditions for generating it, and his battery exemplifies it. A hundred years of Grove will never make a galvanic battery, if there be $20,000,000 that wants his invention.

Another point which has been made much of on one side, namely, that if

Reis had succeeded in transmitting speech, that it is incredible that no more should have been heard of it, and that it is extremely unlikely that such a success should have remain uncredited for so many years as to be almost lost sight of. But the answer is at hand. It is not denied that Yates, of Dublin, did transmit speech telephonically, in 1866, with his improved Reis apparatus. Did it attract any attention? Was it even chronicled? Why was no public mention made of it? Simply because it was considered a curious toy and not of commercial importance.

To sum up then, in my opinion:

1st. Reis invented a speaking telephone capable of transmitting words, that he intended it for that purpose and used it with success, for he says in his so-called *prospectus* when giving directions for using it "sing," "speak" He also says directly in one of his lectures, "*words were transmitted.*" This is also the testimony of a considerable number of those who were with him, Quinke, Messel and others. One of the most eminent scientific men in the United States said to me: "The testimony of Quinke alone is enough to settle that point."

2nd. That Reis's transmitter works in precisely the same way, while transmitting speech, as do the modern ones, namely by what is called *microphonic action.*

3rd. That the only difference of any importance between the Reis transmitter and the modern commercial one, is in the material, carbon being substituted for platinum for an electrode, which renders it more efficient but does not change the method of operation.

4th. That the main reason why Reis obtained no better results than he did, was due much more to the lack of sensitiveness in his receiver than to defects in his transmitter. The weaker vibrations though present, being so much diffused as to be often inaudible. The modern receiver is more efficient on account of its boxing. There is no principle or mode of operation in the modern telephone, which was not known and embodied in instruments made for the purpose twelve years before the famous patent of 1876. This patent could not have been for a *new art.* The Bell Company knows all this as well as anyone, and is in constant fear that the courts will find it out. Ask a Bell man: "What is a Reis transmitter?" and he will answer: "One that will not transmit speech." "What is a Bell transmitter?" Ans. "One that will transmit speech." "If a Reis transmitter transmits speech, whose transmitter is it?" Ans. "Bell's."

To show that I am not alone in my opinion upon these points I append the opinions of other scientific men in the country to whom I applied, asking them to state what their views were upon Reis's telephone, and give me permission to quote them. As will be seen, there are not two opinions about it any more than there are two opinions as to whether the earth is flat, though there may be here and there a man like "Parallax" in England who is stoutly defiant.

Yours truly,

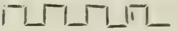
A. E. Dolbear.

PHYSICAL LABORATORY OF WASHINGTON UNIVERSITY,
ST. LOUIS, May 21, 1885.

PROF. A. E. DOLBEAR :

Dear Sir :—Replying to your question concerning the difference between the action of the Reis transmitter and the ones now in use by the Bell Company, I reply that I cannot see that there is any difference in the method or manner of working. It is a source of amazement to me that the courts have decided differently, and I regard it as a very great disgrace, arising I hope from ignorance.

I do not think that either Reis or Bell were perfectly successful in describing the working of the transmitter, but of the two Reis is ahead.

Reis describes clearly the character of sound-waves, and wishes to have these sound-waves act upon his transmitter so as to produce changes of a similar character in the electrical apparatus, in order that these sound-waves may be again reproduced by his receiver. He seems to have fixed his attention upon the magnetic field, or magnetic condition of his receiver, and knowing that a break in the circuit did not abruptly extinguish the current, by reason of the self-induction of the wire coils, and that the closing of the circuit was followed by a gradual rise to the maximum current, he thought a make and break between spring contacts would accomplish what he clearly saw was necessary. He knew also that similar retardation occurred in the magnetization and demagnetization of the iron core. He seems to have understood all this much more clearly than Bell, who draws lines like this  to represent the case of a make and break circuit.

Reis seems to have intended to produce wave-like changes in the magnetic condition of his receiver, and this is precisely what is necessary, *and it is precisely all that is necessary, in order to transmit articulate speech.*

When a circuit containing an electro-magnet is opened and closed, the changes in the magnetic condition of the magnet are necessarily wave-like, and Reis may have thought therefore that a make and break would serve to accomplish the result at which he aimed. But we know now that under the conditions which are supplied in the Reis transmitter, the wave-forms are not of the proper shape to reproduce speech if the circuit is opened and closed at the working contact. The fact is that when the Reis instrument does transmit speech, the circuit does not open and close, and whatever Reis may have thought about it, it did not make and break the circuit when it worked successfully in his hands. It worked by varying the resistance at the loose contact, precisely as the "modern" instruments work to-day. The result at which Reis aimed was to produce the proper variations in the magnet strength. He succeeded in doing this in an imperfect manner. But that he did succeed in doing it I cannot doubt. His main weakness was in the receiving instrument, which was not sensitive enough.

What I have written here seems so clear and evident to me, that I cannot avoid thinking ill of a man who says it is not true. Unless other considerations prevent, I class him among those who say the earth is flat.

I am not in any way financially interested in any kind of telephone, but I

think it is time for scientific men to speak out on this subject, and so far as I happen to know they are practically of one mind.

It is not very likely to influence the legal decisions, but it may at least relieve American scientific men of the disgrace of giving even tacit countenance to a monstrous imposition. Very sincerely yours,

FRANCIS E. NIPHER.

3208 RACE STREET, PHILADELPHIA, Pa., July 22, 1885.

PROF. A. E. DOLBEAR,

Dear Professor:—(1.) There *will* be a telephone report.

(2.) I had supposed, without pretending to be a specialist that there was but one way a telephone *could* work, and that therefore Reis had the idea which was made available later. I have not made that accurate historical research without which I simply should hold my judgment in suspense.

(Signed) Yours truly, LEONARD WALDO,

Yale College Observatory.

STATEMENT.

Having received a Reis instrument, same as "Fourth form" described in Reis's own paper "On Telephony" in the annual report of the Physical Society of Frankfort-on-the-Main for 1860–61, (see p. 20 of Thompson's "Reis Inventor of the Telephone," I had no slight curiosity to know whether it would or not transmit speech.

I connected my lecture room with the Physical work shop using about twenty lbs., of 18 office wire, one Grenet cell, and two Bell receivers in circuit. One of the receivers was located at opposite end of line in shop, while the other and Reis transmitter with the battery were on my table.

After securing fine *singing* adjustment (by *singing* I mean one that would cause the Bell receiver at my ear to hum freely when talking with the Reis) I found that my assistant in the shop could carry on conversation quite readily—so much so that we were both astonished at the results. He called others into the shop, and in more cases than one we fooled the hearers so completely that they supposed that we were using the regular Bell outfit at my end of the line.

We still use the circuit for communication between lecture room and shop without difficulty.

Surely no one who had ever seen a Reis Telephone could claim thereafter to have invented the system of transmission of speech by electric pulsations or undulations.

(Signed) JOHN B. DEMOTTE,

Prof. of Physics.

De Pauw University, Greencastle, Ind., July 21, 1885.

SHEFFIELD SCIENTIFIC SCHOOL OF YALE COLLEGE.

NEW HAVEN, Conn., June 3, 1885.

PROFESSOR A. E. DOLBEAR:

Dear Sir:—It is certainly my impression that Reis's telephone embodies all the essential features of the systems now used and that if it had been

generally known, the exclusive patents which have proved so valuable would not have been granted; but I am unable, under the pressure of annual examinations and much other work, to undertake to either write out a carefully formulated opinion, or to make experiments in a field which is now chiefly of a historical or technical interest.

Yours very truly,

(Signed) CHARLES S. HASTINGS.

OHIO WESLEYAN UNIVERSITY,
DELAWARE, O., June 30, 1885.

PROF. A. E. DOLBEAR, *Tuft's College, College Hill, Mass.:*

Dear Sir:—I have been experimenting with a telephone, made according to the description that Reis gives of one that he made. It is an exact pattern of the one described by Reis. I am irresistibly forced to these conclusions from all the knowledge I can gain on the subject, viz., that Reis did invent a speaking telephone, and that as he invented and constructed it, it is capable of transmitting articulate speech, and that it did so in Reis's hands, and that as a transmitter it substantially works in precisely the same manner as any modern transmitter does when transmitting articulate speech. Reis's invention, the telephone, was undoubtedly what he made, he probably did not fully understand its mode of transmitting speech, nevertheless he made a telephone that in my hands fully and completely transmitted entire sentences. Reis's description of the operation of his instrument is one thing and its work another in my opinion; his invention is the telephone, an articulate speech transmitter, and not a description of its operations.

I am, very truly yours,

(Signed) W. O. SEMANS,
Prof. Chem. and Physics.

COLUMBIA COLLEGE, N. Y., May 28, 1885.

A. E. DOLBEAR, Esq.:

Dear Sir:—In answer to yours of April 29th, I would say, that in my opinion the Reis transmitter, when made and adjusted as the maker intended, is capable of transmitting articulate speech, operating like the Blake transmitter, the action being microphonic, and differing only in efficiency from modern instruments of this class; in other words, Reis in my opinion invented a speaking telephone, operating with precisely the same kind of currents now so commonly employed, the defect of the apparatus being in the lack of sensitiveness of the receiver.

Very truly,

(Signed) OGDEN N. ROOD,
Prof. of Physics in Col. Col.

DEPARTMENT OF PHYSICS, CORNELL UNIVERSITY
ITHACA, N. Y., June 1, 1885.

My Dear Professor Dolbear:—I am under obligations to you for showing me, while you were in Ithaca last week, a genuine Reis by which, when used as a transmitter in connection with a Bell magneto telephone as a

receiver, conversation could be carried on with nearly the same facility as by the Blake transmitter. The experiment showed conclusively that the Reis telephone, with only platinum contacts, not only can transmit speech, but does so so clearly and distinctly that if we had not something better it would be considered a thoroughly successful transmitter.

Had Reis succeeded with his receiver as well as with his transmitter the speaking telephone would have been in universal use ten years earlier than it was.

Yours very truly,

(Signed) WM. A. ANTHONY.

Prof. of Physics.

PRINCETON, N. J., May 28th, 1885.

My Dear Professor Dolbear:—As to the matter we talked about, the case stands about thus in my opinion. Reis set out to make an instrument that would convey sounds electrically; there is no evidence that there was in his mind any limitation whatever as to the kind of sounds to be conveyed, and there is on the other hand considerable and conclusive evidence that he had in mind articulate sounds as well as musical tones. He constructed apparatus which would communicate musical sounds very well, and articulate speech partially; that is, he occasionally got speech through it: but not hitting upon *carbon* as the material of his transmitter electrodes, his success as regards articulate speech was not complete or satisfactory.

Being no business man, and looking at the thing from a scientific rather than a business point of view, he took out no patents, and made no attempts that I ever heard of to introduce his invention as anything more than a piece of interesting scientific apparatus. He did *publish* his results somewhat widely, and his instruments were put on sale as scientific apparatus.

His instruments, just as they came from his hands, will talk now, if manipulated carefully enough, and if *improved* by merely inserting a bit of carbon at the loose contact of the transmitter, would to-day answer satisfactorily for telephonic business; though of course any one would admit that the receivers and transmitters now in use are better than such an apparatus would be. But his *receivers* will any of them operate fairly well with our modern microphone transmitters, and his *transmitters*, fitted with carbon electrode are excellent, even judged by the latest standard.

The fact that he spoke of his transmitter as working by "opening and closing" the circuit, and did not enter into any discussion as to the question of the completeness of the "make and break" in the transmission of words, does not appear to me to justify at all any attempt to deprive him of the credit of his invention. Perhaps the question did not raise itself in his mind, and perhaps it did; but however that may be, he invented an apparatus that would talk—rather capriciously it is true, for want of carbon, but still, when exactly adjusted, it would talk until the adjustment was disturbed. Nor, I think, can there be any question that the action of his apparatus, when thus talking under successful adjustment, is precisely the same as it would be if one of the electrodes was tipped with carbon, and the same also as the action of any of the ordinary carbon transmitters now in use.

As to the precise nature of the action at the "loose contact" of a transmitter, I think no one is yet entitled to speak with confidence. That it *may* consist of actual "makes and breaks" of the current in the ordinary acceptation of the term is proved to my satisfaction by McDonough's revolving wheel experiments; that it *may* consist on the other hand in a rapid variation of the strength of the current without complete "makes and breaks" is of course possible, since in the magneto telephone this is unquestionably the way the current acts. But as I view the matter, *whatever* the action may be, no man has a right now to claim exclusive ownership of it for having discovered an explanation of it, even if his explanation should turn out to be more accurate and exact (which need not yet be admitted) than that of the man who first used that action for the transmission of words. If Mr. Bell's explanation proves correct, well and good, he deserves *scientific credit* for it, but not *patent right* in it, as against Reis.

I do not know that this letter will answer your purpose, but if you can make any use of it, it is quite at your service to do what you like with it.

Very truly yours,

(Signed) C. A. Young.

U. S. Department of Agriculture.—Division of Chemistry.

Washington, D. C., May, 21, 1885.

Prof. A. E. Dolbear, *College Hill, Mass.*

Dear Sir:—I have had the pleasure of testing a model of the Reis telephone, and was surprised at the distinctness with which his transmitter allows the passage of articulate speech. In the trial which I made of the instrument, the distinctness of the transmitted conversation was as marked as that of the ordinary telephone.

It seems to me that the only difference between the Reis transmitter and those of the modern telephone is in efficiency and not in principle. The trouble which Reis encountered in his experiments I am now convinced, was in his receiver and not in his transmitter. Had he been provided with a receiver as delicate as those now in use, the telephone would have been a commercial success twenty years ago.

The transmitter which was used in the trials made in my presence was an exact reproduction of the one described in Reis's original drawings; and the result of the experiment leaves no doubt in my mind that Reis was the inventor of a speaking telephone.

Messrs. Richardson and La Dow, who were with me during the experiment were also much pleased with the excellent action of the instrument.

Respectfully, (Signed) H. W. Wiley.

Ann Arbor, Mich., June 17, 1885.

Prof. A. E. Dolbear:

My Dear Sir:—I can confidently assure you that I have heard speech transmitted in a satisfactory way by means of a Reis's transmitter. The instrument was a careful copy of one of the forms figured in Thompson's

book on Reis's telephone, and the results were nearly or quite as satisfactory as I usually obtain with more recent forms of patented instruments.

Sincerely yours,

CHARLES K. WEAD,

Prof. Physics, Univ. of Mich.

NORTHWESTERN UNIVERSITY,

EVANSTON, Ill., Oct. 10, 1885.

PROFESSOR A. E. DOLBEAR,

Dear Sir:—Respecting the Reis telephone, the evidence appears to me to be entirely conclusive on three points:

First. The Reis telephone, or a faithful copy of it, transmits speech to-day, "with a distinctness sufficient for everyone" to understand plainly.

Second. It transmitted during the lifetime of Reis himself. Of this we have evidence from contemporary printed accounts of its performance, and from *ear-witnesses*, if the word may be allowed.

Third. Reis designed the "*Telephone*" to transmit speech. His own account of "Telephony," published in 1862, is unmistakable on this point.

Philip Reis conceived the idea of transmitting speech and music by Galvanic Electricity, and constructed an instrument that actually did this, even though the laws of the composition of vocal and other sounds were not at that time well understood; and he should certainly have the credit arising from so great an invention. Very truly yours,

(Signed) H. S. CARHART,

Prof. of Physics.

BOSTON, Oct. 10, 1885.

PROFESSOR A. E. DOLBEAR,

Dear Sir:—In reply to yours asking for information concerning my knowledge of Philipp Reis and his relation to the telephone would say that I had, previous to 1881, become so much interested in the subject that, happening to be in Germany, I resolved to visit the field of his labors that I might not only satisfy my curiosity but also judge for myself from the testimony of living witnesses, and from apparatus which Reis has left of the character of the work accomplished by him. Near the centre of the small village of Friedrichdorf, and directly opposite the Post Office, stands the modest house where Philipp Reis formerly lived and which is still occupied by his family. There remain many evidences of his former presence. In the casement of the sitting-room window, electrical binding posts with wires leading to a room in the rear may still be seen. Placed there by Reis himself and used by him in making probably the greater part of those important investigations in the endeavor to perfect his apparatus for the transmission of speech. This was his aim and anything short of that he considered of little importance—so said Mrs. Reis. A short distance further up the main street stands the Garnier Institute, where Reis as a teacher displayed a wonderful ingenuity in devising apparatus for illustrating the usual experiments in Physics and also evinced, as shown by several pieces in the collection, an originality in invention and research of a very high order.

Prof. Leon Garnier, Principal of the Institute, said he had often witnessed Reis's telephone experiments and repeated many words and sentences which he himself had heard through the apparatus.

I was next introduced to Herr Henry Holt. He thus related his first successful experience with the telephone. "I had been listening a long time, and heard nothing intelligible, when suddenly I plainly heard the words, '*I am through; come up.*' I went up, and was considerably surprised to find that that was exactly what Reis had said, and he then explained to me that the speech had been transmitted by the electric current." Mr. Holt said Reis was at the time highly elated over it. After that, he listened with much greater faith, and hence with closer attention, and, on many occasions, heard words and sentences. Reis was evidently sorely tried by the incredulity of those who, in the earlier experiments assisted him, and who, consequently, were very careless and inattentive listeners. Many a joke did poor Reis encounter from his co-laborers and associates, but he eventually silenced them all; and, although they could not realize its importance, they yet recognized the fact that Reis had then made a speaking telephone, and that it was to him as the inventor of the speaking telephone, that the monument in the cemetery at Friedrichdorf was erected by the Frankfort Society. Many have, as you know, for selfish reasons, endeavored to belittle that testimonial by claiming that it was the invention of the *musical* telephone, which it was intended to commemorate. Owing to the difficulty of making such delicate tests before a popular audience, the transmission of musical tones was given prominence at his lecture. It was with much pleasure that I visited the very building and room at Frankfort, in which that famous first lecture of Reis on the telephone was given, and strolled through the garden, across which the wires, on that memorable occasion, were stretched.

The original manuscript in Reis's handwriting had previously been shown to me by Mrs. Reis; she still has it I believe in her possession.

At the shop and factory of Albert, philosophical instrument maker, I learned several interesting facts. The Reis transmitter known as the *collar box* pattern was shown to me by Mr. Albert and he said, as seems probable, that it was made previously to the *square box* and subsequent to the bored block pattern. It seems to me that this must have been the order of sequence. I feel sure that Reis did not employ Albert until after his lecture before the Frankfort Society where the *bored block* transmitter was used; moreover, Albert says he made the collar box pattern himself and this more nearly resembles the *square box pattern*; involves the same ideas; and seems like its crude beginning.

The *collar box* and the *square box* patterns were, however, not intended as superior instruments *i. e.* instruments from which Reis could himself obtain better results, but were so made because they were automatic in their action. At that time there was a call for his apparatus and Reis reasoned that an instrument which dispensed with such delicate adjustment as the *bored block* required would be better to put into the hands of the unskilled experimenter.

Mr. Albert said there was a great difference in the performance of the

transmitters even when made as nearly alike as possible. I have myself verified this experience of Mr. Albert. For example I have had a dozen of each of the parts of the *bored block* transmitter made and placed in piles by themselves each piece like its neighbor, and interchangeable like the parts of a Waltham watch. When set up, taking a piece from each pile, for each instrument, the transmitters could not be told apart except by the number stamped upon them. Upon testing them a great difference was observed in their performance. With some, talking could be transmitted at once, while others needed much adjusting and patience before they would do well even if they ever would. This explains why the various early writers concerning these telephones differ as to their capabilities. Some by chance obtained good instruments, others not so good although all seemed alike.

It was my good fortune, while in Europe, to obtain a pair of instruments which were exact fac-similes of those now held by the German Government and claimed to have been the first set sent out by Reis.

The transmitter was of the square box pattern and the receiver (the knitting needle pattern) corresponded to Pisco's minute description.

With these instruments I have at various times performed many hundred experiments. I have heard both words and unexpected sentences as plainly as with the best modern instruments. When so transmitting speech, the transmitter does its work in precisely the same manner as does the Blake, Edison, or other ordinary varying-contact transmitter. The current produced has variations precisely similar to the variations caused by carbon transmitters. By substituting a small piece of electric-light carbon for piece of platinum foil, which terminates one of the electrodes of the *bored blocks* transmitter, I have obtained an instrument as good and as practical as a Blake transmitter. Indeed, the latter is then but a close imitation of the *Reis bored block*. With a transmitter thus modified, the Reis knitting needle receiver is a good practical receiving telephone. Its tones are clear and articulation excellent.

As the result of my investigations and experiments, I am thoroughly convinced that the Reis apparatus can and in the hands of Reis did transmit articulate speech, and that Reis should and will go down in history as the first and original inventor of the Electric Speaking Telephone.

(Signed.) H. C. Buck,

Electrician, 70 Washington St., Boston.

Prof. A. E. Dolbear:

Dear Sir:—I tried in connection with Prof. Van Dyck the Reis transmitter (an exact duplicate of the instrument made by Prof. Reis as I am informed and believe) with an ordinary receiver, and was surprised at the ease and distinctness with which I could hear the sentences transmitted. They seemed at times as clear as though sent by the modern telephone, but the instrument required occasional adjustment. It seems to me there is no doubt that Reis invented a speaking telephone that worked on the same principle as the modern one and not by a make and break circuit, though I am not certain what his theory about it was. I think his telephone would have successfully

worked in the transmission of speech if his receiver had been sufficiently sensitive. The fault was chiefly in the receiver and not in the transmitter. The telephone of to-day is an improvement on his, but retaining the same principle on which his works—variation of current from variation of pressure.

Very respectfully,

(Signed.) George B. Merriman,

Prof. Astronomy and Mathematics, Rutgers College.

New Brunswick, N. J., August 22, 1885.

College Hill, Sept. 27, 1885.

Prof. A. E. Dolbear:

Dear Sir:—In reply to your request I will say that in the Spring of 1878, while studying for the degree of Master of Arts at Tuft's College, I undertook a series of experiments in telephony, much of my time being spent in working with Reis's transmitters.

The results obtained were by no means uniform, but very often whistling, singing, and *talking* were reproduced with great power and clearness.

No intelligent physicist can for a moment fail to perceive the close similarity in every essential detail of Reis's transmitters and the more improved instruments of modern date. Each consists of a diaphragm the vibrations of which alter the contact resistance of a point in an electric circuit.

The vibrations of the diaphragm alter the contact resistance at the given point by setting up a varying pressure at that point. This is all there is to the ordinary telephonic transmitter.

Secondary coils are merely accessories; they are not at all *necessary*. The assumption that carbon greatly alters the specific resistance under varying pressures is erroneous. It is true that the contact resistance of carbon points is more manageable than that of most other substances, but good transmitters can be made by employing contacts of almost any conductors.

There is no difficulty in making the unmodified Reis transmitter talk well with almost any good receiver.

The assertion that Reis instruments are necessarily "make and break" instruments can only be made by one financially biased or ignorant of physical laws.

That they do frequently "make and break" is true, but so does the Blake transmitter, if spoken to too strongly. It is far more difficult to adjust the voice to the Reis instrument than to the Blake, but when once the voice is adjusted the Reis talks.

The Reis receiver is not quite so satisfactory. His knitting needle receiver is mechanically poor. The needle should have been perpendicular to the sounding board not parallel to it. Yet in spite of this defect the knitting needle receiver will talk with any good transmitter, Reis's included, and with some of the more modern transmitters, I have heard very good talking.

Reis's electro-magnetic receiver was better; indeed it was identical in principle with Bell's 1876 form.

In conclusion I would say that in view of the historical evidence, in view of the testimony of prominent scientific men still living who are contemporaries of Reis, and in view of Reis's instruments themselves, it seems to me nonsense to assert that Reis did not talk with his instruments or that he did not design them to talk.

Very truly yours,

(Signed.) W. L. HOOPER,

Asst. Prof. of Physics, Tuft's College.

PRINCETON, NOV. 12, 1885.

PROFESSOR E. J. HOUSTON:

My Dear Sir :—An absence has prevented an earlier reply to your favor of Oct. 21.

(1) I have no hesitation in saying that in my opinion Reis was the inventor of the speaking telephone. No one who has carefully studied the literature of the subject can have failed to be convinced of the truth of this position, it seems to me.

(2) Actual experiment with apparatus constructed in accordance with Reis's description of his own apparatus, and with apparatus constructed by Koenig, and sold as an embodiment of Reis's invention, has in my hands transmitted speech and in substantially the same way as the Bell apparatus when employing a Blake transmitter.

(3) Bell has set up a distinction among currents and claimed the use of an undulatory current in the process of transmitting signals for the purpose of "multiple telegraphy" and subsequently he has claimed the use of such currents for the purpose of transmitting speech. The undulatory current was as old as the first experiments with dynamic electricity. It had been expressly spoken of and employed by others before Bell and for a use exactly the same as that for which Bell claimed it in his celebrated patent which is now sought to be made the foundation of the great monopoly! (See Varley's English patent). There can be no distinction in the nature of the currents employed by Reis and Blake, and there is no reason for any distinction between the current employed by Reis and Bell when his apparatus is used as a telephone.

(4) There is not the least reason to doubt that Reis did succeed as he says he did in transmitting speech; since it can certainly be done at present with his apparatus. And there is competent testimony that he did so succeed.

(5) The Reis-Legat receiver is a good one and might be employed to-day in commercial business. Indeed it contains everything which Bell's receiver contains and acts in precisely the same way. One merely has to employ carbon for the contact pieces of the Reis transmitter, instead of platinum, to have an apparatus with which speech can be transmitted with certainty and clearly. *The use of carbon is not the invention of Bell.*

(6) The modern transmitting telephones with variable contact are nothing but Reis transmitters with carbon substituted for Pt.

I have not the least hesitation about taking any one of the positions here assumed with reference to the so-called invention of Bell.

Yours very truly,

C. F. BRACKETT.

NEW BRUNSWICK, N. J., Nov. 14th, 1885.

PROF. E. J. HOUSTON;

Dear Sir:—Yours of the 5th duly received. Not having made any extended study of the telephone in its historical aspects, I have been debating with myself how to reply to your questions seriatim.

I conclude to state what I have done and heard, as matters of fact. I have made a Reis transmitter with thin copper plate and platinum contact point. With this articulate speech has been transmitted most unmistakably, a Bell receiver being employed to receive.

That no absolute break of contact between point and plate of transmitter occurred I inferred from my failure to observe induction shocks while operating. These shocks are painfully prominent when transmitting music in the usual way. Nor could any spark be perceived while transmitting speech. Hence I believe that my Reis instrument does not give zero as minimum of current while transmitting *speech*. So far as my opinion is formed, it is that the *onus probandi* rests with those who assert an essential difference between the Reis transmitter and those of other patterns which operate by producing currents of varying intensity.

I write, as I said, what I can hold to as matters of fact, and I hope you will find it as pertinent to your purpose as would be seriatim replies to your questions. Yours respectfully,

F. C. VAN DYCK.

1346 SPRUCE STREET, PHILADELPHIA, Nov. 4th, 1885.

PROF. E. J. HOUSTON.

Dear Sir:—Having some time ago made a careful study of the Reis telephone, and the literature on the subject including his lecture in German, I shall be happy to answer your questions regarding his claim to the invention of the speaking telephone.

First. I most emphatically declare that in my opinion Reis was the original inventor of the speaking *Electric* Telephone.

Second. This question is somewhat analogous and must be answered in two parts. The Bell telephone as originally invented by Bell and used by him is a magneto-telephone in which the current is developed by the vibration of the iron plate in front of the pole of the magnet in the transmitter and is therefore unlike the Reis instrument. But the present telephone of Bell in which a battery transmitter is used in connection with the Bell receiver the electric current is "*manipulated*" (if I may use such a term) in precisely the same manner as in the Reis apparatus.

Third. This question is one which in my opinion no one can answer positively for the reason that we do not as yet know whether there is such a thing as a "current of electricity" or what takes place in a conductor during the passage of that force called electricity. Since this is so we can neither say what form this so-called current takes in its passage through or upon the conductor. Even if we assume that there is such a thing as a "current" and that it is capable of assuming a shape it is in my opinion not necessary for the transmission of articulate speech that this current should be an undulatory

continuous one and such as Bell describes it, but may be an interrupted one provided the interruptions in the continuity are so small as to bridge over the residual sensation of the ear *i. e.* $\frac{1}{16}$ — $\frac{1}{164}$ of a second. Moreover this is *the* vital question in the law suits of the Bell Telephone Company against so-called infringers of the patent.

Fourth. The evidence of the contemporaneous literature on the subject as well as Reis's lecture, points indisputably toward the fact that he transmitted articulate sounds, and it is my opinion that with slight improvements in his apparatus Reis could have transmitted articulate speech.

Fifth. It is my opinion that the chief defect was in the want of sensitiveness in the receiver and not in the transmitter.

Sixth. The modern battery transmitter is identically the same as the Reis transmitter with carbon instead of platinum for one of the contacts. In particular I will instance the Transmitter of Berliner. of Boston, which was bought by the Bell Company.

Hoping that these answers will be sufficient for your purposes I will in closing refer you for further information to the expert testimony in the case of Bell *vs.* Clay, in which you will also find all the important papers of the Reis literature. Very truly yours,

C. SEILER.

DICKINSON COLLEGE,
CARLISLE, Pa., Dec. 15, 1885.

PROF. EDWIN J HOUSTON, *Phila.*

My Dear Sir :—Pardon my apparent neglect of your two communications in regard to the Reis Telephone. It was not oversight, nor altogether want of time, and in no degree indisposition, but I happened to be present in 1865 at the trial of Prof. Reis's telephone at Giessen, in Prof. Buff's lecture room.

My recollection is not very clear as to the details of the apparatus or of the testing of it, as I was at that time more interested in many other things, persons, and places, but my recollection of the impression made upon me and as it seemed to me, on Prof. Buff and the others, that it was interesting and curious, perhaps, but not likely to grow into anything of great practical value. The Bell telephone at first created somewhat similar impression, but having acquired more interest in electrical applications in meantime, and electrical science being so much more advanced than in 1865, I regarded it as involving greater possibilities than I had done in case of the Reis instrument. In looking at the latter now, I cannot but regard it as simply born out of due season, a little too early to be appreciated and wrought out into a practicable instrument.

In answer to your interrogatories I would say then: I believe that Reis invented *a* speaking telephone as early as 1865, and that he succeeded in transmitting articulate speech at that time, and at the time I attributed the defects of the instrument, and in that, perhaps, reflected the opinions of others present, to the variable character of the contact of the transmitter, that seemed to be unavoidable in any instrument for the purpose. Regretting the delay, and hoping the above may meet your questions.

I am, yours truly, CHARLES F. HIMES.

417 WALNUT STREET, PHILA., NOV. 21, 1885.

PROF. EDWIN J. HOUSTON,

Dear Sir: My replies to your queries are as follows:

(1.) In my opinion Reis invented an electrical speaking telephone, but he was not the first inventor of that class of telephones. An extended and critical examination of many certified records and repeated interviews with Antonio Meucci, now of Staten Island, N. Y., have convinced me that he produced a practical speaking telephone as early as 1857.

(2.) When the Reis instrument was operating as a speaking telephone, it worked substantially in the same manner as does the instrument known as the Bell telephone.

(3.) I have never succeeded in transmitting sound by the use of an undulatory current (produced in the manner described in the Bell patent) and in my opinion it is impossible so to do, consequently I consider that when the Reis instrument transmitted speech, it must have been by the use of a current dissimilar to the undulatory described in the specification of the Bell patent.

(4.) I can see no reason why Reis should not have occasionally transmitted words, and I consider the testimony relating to the performances of his telephone to be conclusive, especially when coupled with results which are occasionally obtained by the use of instruments made in accordance with the descriptions published contemporaneously.

(5.) The defects of the Reis instruments seem to be chiefly due to crudeness of construction of both transmitter and receiver, but chiefly in the receiver.

(6.) The "modern transmitting telephones of the variable contact type" are interrupters of the electric current. I have clearly demonstrated some time since that unless the current is interrupted, no transmission of speech (or sound) is possible; of course the interruptions must not be of such duration as to become evident to the ear, for in that case communication is prevented by the interposition of gaps which cut off a part of the representative impulses necessary to produce the desired sounds.

The replacement of one platinum electrode by a carbon point undoubtedly allows of a greater separation of the parts without an actual breach of contact, so that interruptions which would otherwise be of too great duration to allow of the transmission of a majority of impulses are bridged over by an elastic conductor of vapor of carbon.

The Telephone of Meucci, to which I have made reference, was very similar to the present Bell receiver, and was used both for transmitting and receiving. It can be readily demonstrated that the result of the successful use of this magneto-electric device is the production of an interrupted and not an undulatory current.

The ordinary contact transmitter produces an interrupted current by breaking the continuity of the conductor, whilst the magneto transmitter produces a precisely similar current by causing momentary cessations of the current in a continuous conductor. Interruptions of the continuity of the current is an essential to successful transmission of speech with either sort of apparatus.

Respectfully yours,

CHARLES M. CRESSON, M. D.

In concluding this brief and somewhat incomplete history of the articulating telephone and of the distinguished part taken therein by its originator and inventor Reis, the author trusts that despite the limited time which a busy life has somewhat grudgingly afforded him for the work, he has been able to show the singularly complete and masterly way in which Philipp Reis, the first and true inventor of the articulating telephone, solved the problem of transmitting sounds of all kinds by means of electrical currents. He will feel satisfied, if even in a slight degree, he has helped to hasten the time when Reis will be universally acknowledged as the man whose genius invented the most wonderful instrument of modern times.

CENTRAL HIGH SCHOOL,
Philadelphia, December 2, 1885.

"ELECTRICITY IN WARFARE."

BY LIEUTENANT B. A. FISKE, U. S. NAVY.

[*Lecture delivered before the* FRANKLIN INSTITUTE, *November 13, 1885.*]

The first practical plan for using electricity in warfare was devised and executed by Colonel Samuel Colt, the inventor of the revolver, who, in 1841, wrote to President Tyler, stating that he had invented an apparatus by means of which he could destroy in a moment the most powerful man-of-war, even though miles away, and asking that the Government give him opportunity for demonstrating the truth of his statement.

The truth of his statement he demonstrated a year later by exploding a torpedo under water in New York harbor by means of electricity. Following up this success, he totally destroyed by similar means an old gun boat named *Boxer*, and six weeks later, in sight of the President, General Scott and others, he destroyed a schooner in the Potomac, distant five miles. Congress at once appropriated $17,000 to continue his experiments and perfect his apparatus; and in two months from this time he blew up the brig *Volta* in New York in the presence of 40,000 spectators. All of these vessels were at anchor; but in the spring of 1843, Colonel Colt demonstrated the further value of his invention by blowing up a vessel while underway in the Potomac, he being at Alexandria, five miles distant.

These performances seemed in that day little short of magic, and their practical value was evident to many; yet they stopped short at this point, and were never resumed. Colonel Colt endeavored to get further assistance from the Government, but without success. For a variety of reasons, the authorities regarded his plans with disfavor, and Colt, disheartened and distressed, was compelled to abandon his invention just at the time when its success was assured but its details not perfected.

But the Russians caught his ideas, and in the Crimean War, we find the harbor of Sebastopol defended by torpedoes many of which were operated by electricity. A few years later, in our Civil War, the electrical torpedo was extensively used by the Confederates in the protection of their harbors. In the Franco-Prussian War, torpedoes were so successfully employed in the defence of harbors, that hostile ships did not even attempt to enter them; and in the Turco-Russian War, the mere suspicion that a harbor was defended by torpedoes was enough, in many instances, to keep a hostile fleet at a surprising distance, for the hostile fleet could not know just how far beyond a harbor the torpedo defence extended.

Since the experiments of Colonel Colt, the electrical torpedo has gradually improved, keeping pace with the progress of the sciences of electricity and engineering; yet the original plan is the basis of the most elaborate and perfect instrument, and to the brain of Colonel Colt we owe the surest defence we have for the cities and harbors of our extensive coast.

At the present day an electrical torpedo consists of a strong, water-tight vessel of iron or steel, which contains a large amount of explosive, usually gun-cotton, and a device for exploding this by electricity; and the most important form is that which is anchored in a channel, and made to explode when an enemy's ship passes near it. These torpedoes are usually called submarine mines.

In our war, most of these torpedoes were not operated by electricity, but by mechanical means, which consisted for the most part of levers protruding outside the case, and so connected with the explosive inside, that when a lever was struck by a passing vessel, a hammer inside was caused to fall upon a cap, just as when the trigger of a musket is pulled, a hammer is caused to fall upon the cap. These mechanical torpedoes were used with considerable

success by the Confederates, and they caused tremendous damage to the Union ships; but they had many defects, on account of which they have been almost entirely supplanted by the more complete, though much less simple, electrical torpedo.

One of the defects of mechanical torpedoes was the danger attending the operation of planting them; another was the danger attending the operation of raising them; another was the fact that it was impossible to tell whether they remained in order, save by the expensive and suicidal plan of seeing if they would explode; and still another defect was, that a mechanical mine did not know a friendly ship from a hostile one, but would sink either with absolute impartiality.

Now, it is clear that an electrical torpedo is free from all these defects, because it cannot be exploded unless a current of electricity be sent through it from a battery on shore or on board ship; so that the only thing to do when it is desired to make it harmless, is simply to disconnect the battery; and when it is desired to put the mine into operation again, the only thing to do is simply to reconnect the battery; moreover, the condition of the torpedo can at any time be determined by sending a very feeble current through it, even though the torpedo be miles away, and buried in water many fathoms deep.

In order to understand how electricity can explode a torpedo, it is sufficient to know that when a current of electricity goes through a wire, it heats it to some extent; and if the wire is small enough, the heat produced is sufficient to make it white hot. Clearly, if powder or fulminate of mercury be in contact with a white hot wire, the powder or fulminate will be ignited, and if this powder or fulminate be enclosed in a tight vessel, together with powder or gun-cotton, a tremendous explosion will ensue. Therefore, in order to explode a torpedo, the only thing necessary is to send a current of electricity through a very small wire, preferably of platinum, which is within the torpedo, and in contact with the explosive.

That part of a torpedo which includes this small wire and its connections, is called the *fuze*. In practice, the fuze is a separate thing, and is screwed into the torpedo case, the wire from the battery coming into the fuze through a water-tight gland, so that, after the fuze has been screwed in, the torpedo as a whole is water-tight, and may be left under water for months without injury.

If the explosive charge is wet gun-cotton, as is now usually the case, the fuze contains fulminate of mercury, and is surrounded by a small charge of dry gun-cotton. The heat of the fuze wire explodes the fulminate, the explosion of the fulminate causes the instant explosion of the dry gun-cotton; and this, in turn, causes the instant explosion of the whole charge of wet gun-cotton in the torpedo.

But it is evidently not sufficient to be able to explode a torpedo; we must also know when to explode it; that is, we must know when the hostile ship is in such a position that she will be destroyed if the torpedo is exploded. Clearly we can know this, if we have a chart showing the exact position of each torpedo, and have also an arrangement by which we can know at any instant the bearing of a ship coming up the channel from two stations properly situated. If the ship comes into such a position that she is in the line of one of the torpedoes as seen from each station, she is clearly on the intersection of those lines and is therefore directly over that torpedo; and the only thing necessary is to touch the electric key controlling that torpedo, thus sending an electric current through its fuze, and causing its instant explosion. Another way is to have the telescopes at the two observing stations so fitted that when both point at any torpedo, the current is automatically sent through that torpedo. Therefore, if the observer at each station keeps his telescope bearing on an advancing ship, electricity will do the rest, and the ship will sink when she comes within the radius of destructive effect of any one of the torpedoes.

But what can be done at night, or in a dense fog?

Evidently these systems will not answer then, because a ship cannot then be seen, and for this reason, torpedoes now are frequently made absolutely automatic, so that whether the time be day or night, or the atmosphere clear or foggy, the mere fact of a ship striking a torpedo, is sufficient to insure her instant destruction.

This result is secured by the use of what is known to electricians as an automatic circuit-closer; that is, a device which, when subjected to certain conditions, automatically bridges over the distance between two points which were separated, thus allowing the current to pass between them. In submarine torpedoes it is usual to employ a small weight, which when the torpedo is struck, is thrown by the force of the blow across two contact points, one of which

points is in connection with the fuze, the other in connection with the battery, so that the current immediately runs over the bridge thus offered and through the fuze. In practice, these two contact points are connected by a wire even when the torpedo is not in the state of being struck ; but this wire is of such great resistance that the current is too weak to heat the wire in the fuze. Yet when the weight above mentioned is thrown across the two contact points, the current runs across this bridge instead of through the resistance wire and is then strong enough to heat the wire in the fuze and explode the torpedo. Now the advantage of having a wire of high resistance between the contact points instead of having no wire between them, is that the current which then passes through the fuze, though too weak to fire it, shows by its very existence to the men on shore that the circuit through the torpedo is all right.

But instead of having the increased current caused by striking the torpedo to fire the torpedo directly, a better way is to have it simply make a signal on shore, and at the same time throw in a firing battery. Then when friendly vessels are to pass, the firing battery can be disconnected, and when the friendly ship bumps the torpedo, the working of the signal shows not only that the circuit through the fuze is all right, but also, that the circuit-closer is all right, so that had the friendly ship been a hostile ship, she would certainly have been destroyed.

The action of the torpedo placed in a harbor and connected by a submarine cable to an electric battery on shore is thus shown to be quite a simple thing. But it should not be gathered from this that the protection of a harbor is a simple thing, or one that can be accomplished in a few days on the outbreak of war. It should be remembered that each torpedo contains from 100 to 1,000 pounds of gun-cotton, that hundreds of topedoes will have to be used, that the amount of gun-cotton required will be enormous and that it will be wanted in a hurry, but that the operation of making gun-cotton cannot be hurried ; it must be remembered that to make the torpedo cases required, will consume much time, that the making of the fuzes is a matter requiring the greatest possible care and calculation, that the operation of properly laying down these heavy and yet delicate torpedoes in deep water even in the best possible weather is an operation requiring great nautical and

engineering skill and practice. Yet even after the best possible system of submarine mines has been laid down, it will be of no use, unless an enemy's boats can be kept from countermining, and unless the operating rooms be furnished with the best instruments, and thoroughly protected against capture, by fortifications, guns and ships. It is no uncommon thing to hear men of intelligence airily say, "Oh, in time of war, we can defend our harbors by torpedoes." I do not think I am exaggerating, when I say it would take a year to put the torpedo defences of our harbors into proper shape, even if Congress were to appropriate the money to-morrow, and after that, a corps of men would have to be formed and thoroughly trained in laying down and taking up torpedoes and cables, making splices in submarine cables, testing circuits, managing electric batteries, etc.

In order to detect the presence of torpedoes in an enemy's harbor, an instrument has been invented by Capt. McEvoy, called the "torpedo detector," in which the action is somewhat similar to that of the induction balance, the iron of a torpedo case having the effect of increasing the number of lines of force embraced by one of two opposing coils, so that the current induced in it overpowers that induced in the other, and a distinct sound is heard in a telephone receiver in circuit with them.

As yet this instrument has met with little practical success, but its principle being correct, we can say with considerable confidence that the reason of its non-success probably is that the coils and currents used are both too small.

Besides these stationary topedoes or mines anchored in harbors, there is another class called spar torpedoes, which are carried on spars protruding from ships or boats, and which consist for the most part of cases of steel holding about thirty pounds of gun-cotton and fitted with electric fuzes, similar to those for exploding submarine mines. The torpedo on the end of the spar is connected by insulated wires with an electric battery in the boat or ship, and it is designed to be shoved under a hostile ship by a determined effort and exploded there. The current is sent through the fuze by pressing an electric key at the proper moment; or a simple automatic circuit-closer may be put inside the torpedo, so that when the torpedo strikes the ship, a break in the circuit is automatically bridged over in the torpedo, thus allowing the current to heat the platinum wire in the fuze and explode it.

Still another class of torpedoes are movable torpedoes.

These contain not only explosive and means for exploding it, but also machinery for moving the whole through the water and for steering it. A movable torpedo is therefore really a torpedo boat and torpedo combined.

In one class of movable torpedoes, such as the Lay torpedo, the motive-power is usually carbonic acid gas, or compressed air, the steering and firing being done by electricity. One wire usually suffices, a simple step-by-step device accomplishing the operation of sending the current through different circuits in the boat, the current through one circuit causing the throttle of the engine to open, the current through another causing it to close, another putting the helm to "starboard," another putting the helm to "port," another firing the torpedo, etc. Therefore, the operator on shore, or on board ship, can, by moving his switch in the proper manner, cause the torpedo boat to go ahead, stop, turn to the right or left, in such a way, as to go directly towards the object of attack, and then explode in contact with her bottom.

In another class of movable torpedoes, the electric current not only steers the boat, but it also propels it, there being an electric motor or engine inside which, when supplied with the requisite current from an electric machine on shore, or on shipboard, revolves rapidly, thereby causing the propeller of the boat to revolve, in the same way that a steam engine causes the propeller of a steamboat to revolve. The current for steering may either be sent along a separate wire, which may be inside, the other one, or a device may be used, by which one wire will suffice for everything.

Movable torpedoes being usually cigar-shaped, so that their section is circular or nearly so, the electric motor for an electric movable torpedo, which will most nearly fit the space intended for it (in other words, the shape which permits the largest size for a given space), is clearly one in which the distance from the centre of the armature to the outside of the magnets is constant, so that the field magnets form nearly a circle embracing the armature. The exterior form of the motor, called the Griscom motor, evidently seems to fulfil this condition well.

The most successful electric movable torpedo thus far tried is the Sims torpedo, with which experiments have been conducted under

General Abbot's superintendence for some time, and with very good results. Now as all men-of-war and all forts are to be supplied with means for generating electricity on a large scale, it is clear that an electric movable torpedo can be easily adapted to naval and military requirements, the mechanism of the torpedo being exceedingly simple, and the only thing to be done, to put it into operation being to connect it to a suitable electric machine, and introduce a key-board, by which the direction and strength of the current can be controlled. The torpedo will then be ready to move at any instant, and will have a supply of power practically inexhaustible.

Recent experiments in England have shown that the Whitehead torpedo, over which control ceases after it is fired, is not so formidable a weapon when fired at a ship under way, as many supposed, for the simple reason that it can be dodged. Now an electrical torpedo, over which control is exercised while it is in motion through the water, cannot be dodged, provided it be given sufficient speed.

For effective work against ships, capable of steaming fifteen knots per hour, the torpedo should have a speed of twenty knots. Now, there is no theoretical difficulty in the way of doing this, for a speed of eleven knots has already been recorded (though an electric torpedo to get this speed would have to be larger than a Whitehead having the same speed), and it may be conceived that a torpedo carrying, say fifty pounds of gun-cotton, capable of going twenty knots per hour, so that it would pass over a distance of 500 yards in about forty-five seconds, and yet be absolutely under control all the time, so that it can be constantly kept pointed at its target, would be a very unpleasant thing for an enemy to meet.

Our Civil War introduced another use of electricity into warfare, and gave birth to the art of military telegraphy. At first, the telegraph was used only communicating along the regular telegraph routes, but eventually a corps of Military Telegraphers was formed, and instant communication became possible between detachments in the field. The advantages of the telegraph in conveying information and orders with despatch was found to be so great that foreign nations took the hint, and to-day a telegraph train is essential to all armies. No well-equipped force in the world is without means for rapidly connecting, by telegraph, dif-

ferent headquarters with each other and with the different parts of an army, and in the Franco-Prussian War it was the telegraph, combined with the railroad, which made possible that wonderful speed and certainty of mobilization and manœuvre that caused the swift destruction of the armies of France.

In military telegraph-trains, miles of wire are carried on reels, in specially-constructed wagons, which carry also batteries and instruments, some of the wires being insulated, so that it can rest on the ground, and thus be laid out with great speed; while other wire is bare and is intended to be put on poles, trees, etc. For mountain service, the wires and implements are carried by pack animals. Regularly trained men are employed, and they are drilled in quickly running lines, setting up temporary stations, etc. In the recent English operations in Egypt, the advance guard always kept in telegraphic communication with headquarters and with England, and after the battle of Tel-el-Kebir, news of the victory was telegraphed to the Queen and her answer received in forty-five minutes.

The telephone also has been used in military operations, and with great success, having an evident superiority over the telegraph for some purposes. One use of the telephone, in fact, is to assist the telegraph in cases where, by reason of the haste with which a line has been run, the current leaks off, so that the receiving instrument will not work. The only thing necessary is to use a telephone to receive the message, and to use as a transmitter a simple buzzer, or automatic circuit-breaker, controlled by an ordinary key. In many cases where the ordinary receiving telegraph instrument refuses to work, the more delicate telephone thus used will work very satisfactorily.

(*To be Continued.*)

An Inglorious Columbus.—Edward P. Vining has published a volume of more than 700 pages devoted to the task of proving that Hwuischan and four other mendicant Buddhist monks discovered America in A. D. 458. Many preceding authorities, which are quoted largely, have noticed or translated Hwuischan's recital. Many resemblances are pointed out between Buddhism and the worship of Quetzalcoatl, parallelisms between the representations of that God and those of Gautama-Buddha, with some curious word-likenesses, and certain Mexican traditions, which seem to contain intimations of Hwuischan's visit.—*Amer. Naturalist, Oct., 1885.*

RAPID TRANSIT AND ELEVATED RAILROADS, WITH A DESCRIPTION OF THE MEIGS ELEVATED RAILWAY SYSTEM.*

By Francis E. Galloupe, M. E., Boston, Mass.

It would be difficult in a paper of reasonable length to treat a subject having so wide a bearing as that of rapid transit, with the exactitude and thoroughness of detail which might be expected in a technical article. The following notes are therefore with hesitation submitted, in the hope that the incomplete form and in some cases the mere suggestions which only can be presented within the limits of this paper, may be accepted in place of a more extended treatise.

The modern demand for increased facilities of transit is twofold. (1.) There exists an imperative need of better means for the conveyance of passengers within all our large cities, making the problem an universal one, although its attempted solution has thus far been local. (2.) There is the more general demand for more rapid means of communication between cities and important centres of population or business.

It is the present purpose to show what the existing requirements are, as indicated by their gradual development, for obtaining with safety a higher speed of transit, and how the problem may be met as it arises, first, locally, and then for transportation through longer distances.

The endeavors made to supply these wants are seen on every hand. Probably most would agree that the time of increased facilities for transit is coming. The world will never go back to slower speed. The tendency is indeed precisely opposite; that is, to save time, shorten working hours, and to concentrate the volume of transactions in centres of business or of trade. Whatever this progress of business and of life demands will be developed and put in practical use.

---

* A paper read at the Boston meeting, 1884, of the Amer. Soc. Mechanical Engineers, and reprinted from advance sheets of the *Transactions*.

Fifty years ago there existed only the very beginning of the present great development of the surface railway system, which has cost in the United States alone nearly $7,000,000,000, and employing 300,000 men, with an extent at the end of the year 1884, of 125,379 miles.* They transported last year 334,814,529 persons, and earned in gross $770,684,908, with interests and dividends paid, to the amount of $269,939,137.

Previous to this the most rapid methods of transit, still within the memory of older men now living, were only post-riding and the now primitive stage coach Not even the horse car had been invented. Later on, the horse railroad system took its place in the streets of our principal cities, and although not developing much increase of speed, its great convenience, as well as the economy shown by the introduction of the principle of carrying passengers by rail, as compared with any other method of land transportation, has caused the growth of this system to the extent of many miles of track and great perfection of detail. In Massachusetts, the present extent of the street railways is 310 miles, as compared with 2,851 miles of steam railways in the State; their value $12,410,631, carrying 94,894,259 passengers in 1884, and employing 3,846 men and 8,996 horses, as compared with about 16,000 employés on street railways in the whole country.

The horse railroad has had so important an influence in the building up of suburbs and extension of the growth of cities as seemingly to have become an absolute necessity; yet so great are the present objections in blocking the streets, failing to supply sufficient accommodations to the public, and loss of time by the delays incurred by passengers, that in the East, at least, it is becoming the general opinion that its limit of capacity and usefulness has been reached nearly if not fully.

While this system has been growing and other methods of obtaining relief from the crowded state of the streets and the consequent retarding of transit have become established, such as the London underground railway and the Vienna depressed railways, a system of elevated railways has been developed in New York

* From Poor's Manual of R. R.'s, 1885. Cost of Roads and Equipment, $6,924,554,444. First Railroad completed in Massachusetts, 1827; first locomotive run, August 8, 1829.

City, of which the results attained in the short period of time since 1872 have been extraordinary. Not only have these demonstrated the fact, not before proved or deemed hardly practicable, that a complete steam railroad system could be run upon the tops of a line of posts set in the streets, as in the Bowery line, with entire safety, speed and convenience, but the permanent success of the principle has been, I think, fully demonstrated. A short statement of their progress is inserted, from a recent paper. "During the first year the roads carried 170,000 persons, and during the past year nearly 100,000,000." "The first year's earnings were $17,000; last year nearly $7,000,000." "There was a steady progress each year." "The aggregate earnings since the road was first built have been $32,000,000; the aggregate passengers carried, $44,000,000."

Such being the facts, let a moment's glance be given at the local conditions existing in cities. Experience has shown that ease of communication in the transaction of business requires its concentration into the least possible space. A street too wide for business purposes is more detrimental than one too narrow. Th result has been the erection of five, seven and even nine story business blocks, which, with the general introduction of fast running elevators, supply the demand for offices and warerooms, and are more valuable for business purposes than lower floors farther removed from the business centre. Now, with this great concentration and consequent increase in the volume of business through the streets, the capacity of the streets themselves has not been increased proportionately.

The result has been a blocking of the streets to a large extent, and the obvious remedy, if the height of buildings is doubled, is to have two-story streets, so to speak, *i. e.*, to relieve their crowded condition and divide the travel by some form of elevated railroad which shall take from the surface that portion of it which desires merely transit as quickly as possible, and thus relieve the one portion from its block and convenience the other.

We must either have rapid transit *upon the surface*, *under it*, *or above* the surface of the ground. The first is impracticable, for reasons to be shown later on, while the second is open to the same objection, on account of the limited field available caused by its

excessive cost.* For general usefulness, the only feasible method is the third.

Objections to this remedy have been of two kinds: (1.) The alleged damage to property adjacent to an elevated line of railway; and (2.) The sentimental one of injury to architectural features of the buildings. The first should be at once recognized where real damage exists, and met so far as practicable by the road. A new element has been introduced with the elevated railway, disturbing the existing business relations and property interests, which latter cannot defeat the railroad, but which must be readjusted after the introduction of this new element. The injury done in places, whether the abuttor's land is held to end in the edge of the side-walk, as in New York law, or extends to the centre of the street, should be compromised between the railroad and property interests, in equity, by the payment of damages, in case either of direct damages by land taken, or of consequential damages, if proved that the rent or income from the property is thereby diminished; but these cases are only incidental in comparison with the great and lasting benefits to the public at large. As to the second objection, it may be said that the demands of transit should be first met, with as little loss in other respects as possible. The primary use and purpose of the streets is for transit, and not for the display of the architectural features of the buildings lining them

Opposition to these necessary facilities for transit, while somewhat surprising when the great benefits to be derived from them are considered, is yet to be expected when we review the history of the introduction of railroads to supersede the turnpike and the stage coach, the introduction of the horse railways even, or that of any of the great improvements, such as many in the progress of manufactures, which have destroyed the value of some class of property which they supersede. All such must, in the end, give way to the public need.

While it has been found that the elevated system is best adapted for long-distance travel, *i. e.*, for distances exceeding a mile, the reverse is true of the horse railway, which will still be found better

* The proposed underground railway for Broadway, New York, is estimated to cost from $800,000 to $1,400,000 per mile, for single and double tracks, respectively.

fitted for the accommodation of some portion of the short-distance passengers than even the elevated railway. Where the time required for conveyance is short, and speed, therefore, not an object, considerations of convenience will still lead the short-distance passenger often to prefer to step upon the cars of the horse railway, which goes directly where he wants to go, instead of climbing up a flight of steps into an elevated railway car, which may not leave him so nearly at his destination ; and especially will this continue to be the case if, as now seems likely, its service becomes improved by the use of electric motors, in the near future.

For the increase of transit facilities, certain definite requirements should be met in any successful system. These may be regarded as those of, (1.) *safety;* (2.) *speed;* and (3.) *convenience and economy.*

The leading features of the surface railway system, viz.: (1.) *the rail and car*, for the reduction of required motive-power and dead weight carried per passenger to their least amount; and (2.) *the truck system*, having independent moving trucks, coupled, supporting upon them the platform and body of the car, should be retained.

Under the requirements for *safety*, should be noted: (1.) safety from derailment, since next to railroad accidents occurring to persons crossing or walking upon the tracks, which are not reported, more than one-half of all reported railroad accidents are from this cause ; (2.) safety from obstructions upon the track. These consist of passing teams, tresspassers and cattle, rocks and timber falling upon it, wash-outs, which are of the nature of obstructions ; in winter, the blocking of the tracks by snow, drifting of the same, and many other causes resulting from railways built at grade, or upon the surface of the ground; (3.) an efficient brake system should be provided that will act automatically should the cars break apart or other derangement occur; (4.) appliances to give the engine-driver positive and absolute control not only of the engine, but over the movement of the entire train.

Among the requirements for any material increase of *speed*, are, (1.) those insuring at least equal safety to that now existing under the increase proposed, such as holding the truck upon the rails by flanges or their equivalent, so that no derailment can possibly

occur by the trucks lifting or jumping away from contact with the rails; (2.) the centre of gravity of the engine and cars should be lowered and the stability of rolling stock increased, to prevent strains which would overturn them; (3.) more secure attachments between the truck and car body should be provided, to prevent the momentum of the car body from breaking away from the former; (4.) there should be provided an improvement in the design of motive-power, especially by the use of independent means for producing adhesion of the driving wheels to the rails; or a controllable and variable adhesion, not dependent upon the weight of the engine for the pressure of the driving wheels upon the rails; (5.) a consequent saving of weight both in engine and cars, with the same power of engine, and reduction of the dead weight carried per passenger, should be reached; (6.) for speed, a clear line to be provided, with no crossings at grade, and the use of an efficient block system.

For the attainment of *convenience and economy* the system used should be adapted:

(1.) For curves of shorter radius than have been heretofore practicable, especially in cities, where streets are narrow; and for through lines, a better allignment as to grades and curves, made possible frequently only where the track is raised above the surface. (2.) For economy in repairs, by possessing freedom from wash-outs or settling of the ground, and from the decaying of cross-ties.

It will be seen that most of the above requirements can be met and the result in view reached only by the employment of an elevated system. It is the belief of the writer that all steam railroads, excepting perhaps those only for freight, having speeds of less than ten miles per hour, should be elevated from the surface of the ground, because of the many advantages of such a construction, as will be shown more fully in the further discussion of this subject. In Massachusetts, a resolve of the Legislature,* referred to the Railroad Commissioners, looking to the feasibility of a gradual abolishment of all grade crossings in the State has already been

---

* "*Resolved*, That the Railroad Commissioners examine and report to the next Legislature upon the subject of providing for the gradual abolition of grade crossings in cities and the populous parts of towns." [Approved, April 19, 1884.]—*Report of R. R. Coms., 1885.*

passed, and this may be regarded as a first step in the direction indicated.

To show that many or all of these conditions may be fulfilled in concrete form and may exist practically, the problem will be illustrated by the selection and brief description of one of the several distinct systems, each containing some excellent features that have been proposed, namely, that of the Meigs elevated railway system, now under construction in the city of Cambridge, Mass.

This plan, invented and developed by Captain J. V. Meigs, of Lowell, Mass., as the result of over ten * years' careful study of the surface roads, their advantages and defects, is unique in that it is a complete system, one part absolutely depending upon the others, and having little or no analogies in the surface roads.

It may be regarded as a development from the New York elevated system, taking for its starting point the fact only that a railroad can be built and successfully run upon a single line of posts.

(*To be Continued.*)

Red Twilights.—M. Hirn sends to the French Academy a notice of observations from his observatory at Colmar, and expresses his surprise at finding that the redness originated at a height far above the ordinarily supposed height of the atmosphere. Without positively committing himself to any hypothesis, he thinks that electricity alone would have been capable of maintaining the extremely rare materials at such a height, if we suppose: (1.) That the extreme layers of our atmosphere possess a powerful specific electricity, and (2.) That the materials were themselves projected with an electricity of the same name.—*Comptes Rendus, Aug. 24, 1885.*

Alloys of Cobalt and Copper.—The alloys of cobalt and copper have a red color, and a fine silky fracture which resembles that of pure copper. They possess a remarkable ductility, malleability and tenacity; they can be easily forged and rolled when hot, but they cannot be tempered. They are obtained by melting copper and metallic cobalt in a crucible under a flux of boric acid and charcoal. G. Guillemin submitted some specimens to the French Academy, prepared from red electrolytic copper and an alloy rich in cobalt and copper with some nickel and iron. The alloys, which he has especially studied, contain from one to six per cent. of cobalt. The alloy with five per cent. of cobalt is particularly interesting for its useful qualities. It is as inoxidizable and malleable as copper, and as tenacious and ductile as iron. It can be used in the manufacture of rivets, fire-boxes for locomotives, tubes, and a great variety of braziers' work.—*Comptes Rendus, Aug. 10, 1885.*

---

* Application for patent filed May 16, 1873; issued May 11, 1875. Earliest notes made in 1867 or 1868.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, December 16, 1885.*]

HALL OF THE INSTITUTE,
PHILADELPHIA, December 16, 1885.

MR. W. P. TATHAM, President, in the Chair.

Present—133 members and five visitors.

Sixty-five persons were reported as having been elected to membership since the last meeting.

The Committee to which had been referred the preparation of a memorial of the late JOHN W. NYSTROM, presented the following report, which was accepted and ordered to be spread upon the minutes, viz.:

"During the year just closing, we have to note the death, at the age of sixty-two years, of Mr. JOHN W. NYSTROM, for many years an active member of the INSTITUTE.

"Mr. NYSTROM was a native of Sweden, and there received a collegiate and technical education. He became a member of this INSTITUTE in the year 1850.

"Mr. NYSTROM was a frequent contributor to the JOURNAL OF THE FRANKLIN INSTITUTE, and participated actively in the discussions incident to the introduction of screw propellers for steam marine service.

"He also edited and published several scientific works, prominent among which are his 'Steam Engineering' and his 'Handbook for Engineers,' the latter has run through several editions and has a place with mechanics among standard books of ready reference; he invented a calculating machine and a number of minor improvements in steam engines.

"Mr. NYSTROM originated and proposed to publish and introduce a new system of enumeration instead of the decimal system, in which seven and fifteen were the highest integral figures instead of nine; he also devoted considerable attention to a new system of musical notation, neither of which, though showing great ingenuity and clear perception of the defects of existing systems, could be brought into use in view of the almost universal hold of the present systems.

"The readiness with which he submitted new symbols in his engineering works indicates the inclination and aptness of his mind for concise expressions.

"Mr. NYSTROM's forte and pleasure was in making mathematical formulæ, with which he was ever ready.

"He was an industrious member of the Committee of Science and the Arts, and will long and pleasantly be remembered by the members of the

committees with whom he was associated, as an honest and ready disputant, a cheerful and most untiring worker.

(Signed) "H. R. HEYL, *Chairman*,
"WM. BARNET LE VAN,
"S. LLOYD WIEGAND."

The following nominations for officers, to serve respectively for the term set opposite each name, were made:

For *President* (to serve one year), ... CHAS. H. BANES.
For *Vice-President* (to serve three years), ... FRED'K GRAFF.
For *Secretary* (to serve one year), ... WM. H. WAHL.
For *Treasurer* (to serve one year), ... SAM'L SARTAIN.
For *Auditor* (to serve three years), ... WM. A. CHEYNEY.

For *Managers* (to serve three years):

FRED'K FRALEY,	WM. P. TATHAM,	WM. H. GREENE,
PERSIFOR FRAZER,	WM. H. THORNE,	CHAS. H. HUTCHINSON,
WM. HELME,	JOHN J. WEAVER,	WM. D. MARKS,
EDWIN J. HOUSTON,	WM. L. BOSWELL,	SAM'L R. MARSHALL,
ENOCH LEWIS,	GEO. V. CRESSON,	E. ALEX. SCOTT.

Mr. WM. SELLERS made some appropriate remarks touching the many and valuable services rendered by the retiring President, and, in conclusion, offered a motion tendering him the thanks of the INSTITUTE. The motion was numerously seconded, and, being put to the meeting by the Secretary, was carried unanimously.

Prof. EDWARD F. MOODY then read the paper of the evening, on "The Channel of the Delaware River at Philadelphia." The paper gave an account of the past condition of the river channel, as shown from fragments of history, old surveys, etc.; dwelt upon the gradual filling up of the Philadelphia side of the channel, the causes and possible consequences thereof; and described the dyke now in course of construction at Fisher's Point above Petty's Island, under the direction of the Government engineers, as the most effectual means of checking the silting up of the Philadelphia channel, and of securing and maintaining a depth of channel required for the present and future commercial needs of the city. The paper was discussed by Messrs. Tatham, Sellers, Orr, Houston, and others, and has been referred for publication in the JOURNAL.

Adjourned. WM. H. WAHL, *Secretary*.

BOOK NOTICE.

TUNNELLING UNDER THE HUDSON RIVER: Being a Description of the Obstacles Encountered, the Experienced Gained, the Success Achieved and the Plans Finally Adopted for Rapid and Economical Prosecution of the Work. By S. D. V. Burr, A. M. (Illustrated by working drawings of all details. Twenty-seven plates.) New York: John Willy & Sons, 15 Astor Place. 1885.

The announcement of "A Description of the Obstacles Encountered, the Experienced Gained, the Success Achieved and the Plans Finally Adopted

for Rapid and Economical Prosecution of the Work," comes to those who have followed the rise and progress of the tunnel under the Hudson River, like a promise of fulfilment of long desired knowledge from an authoritative standpoint. The careful and interested reader of what Mr. Burr has written cannot fail to be disappointed in the results of *his* work; ambiguous description and lack of perspicuity in style, leave the reader with very uncertain impressions upon methods and details about which he naturally expected at least clearness enough to permit the conclusion that he understood what Mr. Burr attempts to describe. The value of the book should consist in leaving the reader in possession of all the writer had seen, and in this it too frequently fails.

To one who had visited the work while it was in progress, Mr. Burr's description would probably be clear, but his manner of writing lacks just that perspicuity which is requisite to convey to the otherwise uninformed reader clear impressions and ideas of what is described.

If it was necessary to place the only description of the character of the material through which the tunnel was driven, near the end of the book, it would have been wise to suggest in the preface that Chapter VII might with great advantage be read earlier in the work.

In general terms, it is of great value to know just what degree of success was obtained in driving a tunnel through such material as forms the approaches and bed of the Hudson River at the site of the tunnel; this is naturally established by the existing work done, beyond this simple text the descriptions in question are often unsatisfactory. The engineer can generally gather as much valuable information from a recital of failures as from a statement of successes, and, while it may require a large measure of heroism to give the public the former, it is none the less desirable that the historian should do so. Mr. Burr has hardly met this requirement. As a whole, the book is of value in being the only connected history which so far has been written of the work, but it is to be hoped that the completion of the tunnel will be followed by a more complete and pains-taking narrative which shall supply the defects which seem to belong to the present book. L. Y. S.

New Map of the Solar Spectrum.—Thollon has presented to the French Academy a map of about one-third of the prismatic spectrum, which was constructed at the Nice observatory after four years of assiduous labor. It is more than ten meters long and contains 3,200 lines, or twice as many as are given in Angström's atlas. The chart is divided into four bands, No. 1 giving the spectrum when the sun is 80° from the zenith, and for a mean hygrometric condition of the atmosphere; No. 2, when the sun is 60° from the zenith and the air is very moist; No. 3, for the same zenith distance and a very dry air; No. 4 gives the pure solar spectrum which would be obtained if one could observe outside of the atmosphere. This arrangement enables one readily to recognize all the telluric bands, and also to distinguish those which come from constant elements from those which are due to the variable elements of the atmosphere.—*Comptes Rendus, Sept. 7, 1885.*

An Incipient Water-Spout.—Captain Charles Haley, of the three-masted schooner *Genevieve*, gives the following account of his remarkable experience on October 29, 1885, when about thirty miles south of Frying Pan Shoals Light Ship.

The weather was clear and pleasant, and a light breeze blowing from about W. N. W. The vessel was going through the water about four knots, heading N. E. by E. under all sail. He was standing aft on the deck about 10 A. M., when he heard a sizzling sound aloft, and immediately sung out to the crew to clew up the topsails. The next moment the topsails gathered up in bunches, and the main and mizzen-masts were twisted off about twenty feet below the crosstrees and taken overboard. At the same time the jib and foresail were flapping to windward with each roll of the vessel, and where he was standing aft, an open umbrella could have been held without difficulty. The mate of the vessel said, that he had noticed, just before, a small cloud to windward, which looked like the beginning of the formation of a water-spout. Almost immediately after the disaster the sun came out bright and clear again. About 2 P. M., the same day, a gale sprung up from S. W. and blew for twenty hours.

Undoubtedly the *Genevieve* experienced an incipient water-spout. The condensation of the aqueous vapor, which was being carried up by the ascending currents at the centre, had not advanced sufficiently to become visible. The dew point was probably low, and the small cloud noticed, quite high. The sizzling sound was caused by the swift gyratory motion of the currents of air. Had the *Genevieve* not been in the path, it is probable that the water-spout would have been fully formed within a short distance. The gyratory currents would have descended to the surface, the vapor would have condensed as it ascended into the atmosphere, and if the atmospheric pressure in the centre had become sufficiently diminished, the sea water would have risen until the base of the spout was fully formed. The friction against the masts and sails of the *Genevieve* probably retarded the gyratory currents sufficiently to break up the incipient formation.

The white squalls, which are so dreaded by sailors in certain latitudes, are similar to tornadoes and water-spouts in their formation. There is so little moisture in the air that no vapor condenses, and in consequence, the column remains invisible. Generally, however, the boiling of the sea beneath the column is a sufficient indication of their proximity. A. B. W.

The Tornado, which crossed the Delaware August 6, 1885, and destroyed the upper works of the steamer *Major Reybold*, was very similar in some respects to the one experienced by the *Genevieve*. Numerous observers stated that the apex of the Philadelphia tornado was about 100 feet in diameter when it struck the *Reybold*, and it did not disturb the surface of the water while crossing the river. If the salt works and other buildings on the Neck had not disturbed the progress of the apex, the observers along the wharves of Philadelphia might have been treated to the strange sight of a water-spout on the Delaware. A. B. W.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXI. FEBRUARY, 1886. No. 2.

"ELECTRICITY IN WARFARE."

BY LIEUTENANT B. A. FISKE, U. S. NAVY.

[*Lecture delivered before the* FRANKLIN INSTITUTE, *November 13, 1885.*]

[*Concluded from Volume CXXI, page 69.*]

In endeavoring to use the telegraph and telephone for strictly naval purposes between ships, a number of obstacles have been met which have not yet been overcome, though many ingenious devices have been attempted. It might seem at first sight as if, in the case of ships at anchor, telegraphic and telephonic communication among the ships, and between the ships and shore, would be an easy thing to establish. It is easy, and it has been established in the case of ships moored so that they cannot swing; but when a ship swings by a long chain, most of which is imbedded in the mud, it becomes very difficult to devise an automatic means to keep the wire from being fouled and broken. In England, in the case of a lightship, the difficulty has been surmounted, or rather avoided, by making the cable, by which the ship rides, hollow, and running an insulated wire along the long tube thus formed inside.

This plan has been found thus far to work very well, even in the worst sort of weather.

But the problem is much simplified when temporary communication only is desired between ships at anchor, between a ship and the shore, or between a ship and a boat which has been sent off on some special service, such as reconnoitring, sounding, etc. In this case, portable telephones are used in which the wire is so placed on a reel in circuit with the telephone, that communication is preserved, even while the wire is running off the reel.

The telephone has been used to some extent on shipboard for communicating between different parts of the same ship, giving orders to the magazines, battery, etc. The vibration of a ship is seldom so excessive as to impair the working of the microphone transmitter; and in cases where it is excessive, the original magneto transmitter has been found to work perfectly, getting rid entirely of trouble, due to vibration, and at a cost only of a little of the loudness of tone as heard in the receiver.

The telegraph and telephone are both coming largely into use in artillery experiments and drills, as in tracking a vessel as she comes up a channel, so that her exact position at each instant is known, for determining the spot of fall of a projectile, etc. In these cases two observers, at the ends of a base line electrically connected, know at each instant the bearing of the vessel, or the projectile, from both ends of the base line, and the intersection of these lines of bearing is, of course, the position of the vessel or the projectile at that instant. In the case of a vessel, this gives the range for the guns, and in the case of a projectile, it shows how much the projectile missed the target. In getting the time of flight of projectiles also, electricity is of value, since it enables the observers to get the exact time of start, a thing impossible to get with stop-watches, but by making the projectile break a wire in circuit with a chronograph, the precise instant of start at least to a thousandth of a second is automatically registered.

An application of electricity, somewhat analogous to this, has been in use for years in what are broadly called velocimeters; that is, instruments for ascertaining the velocity of projectiles. There are scores of patterns, but in all, wires are cut by the projectile at different points of its flight, and the breaking of each wire causes the breaking of the electric current going through it; and this

causes the appearance of marks on a surface moving along at a known speed.

Now, knowing the rate at which this surface moves, and observing the distance on the surface between the marks caused by the breaking of the first wire, and the marks caused by the breaking of the second wire, we can compute the interval of time, which elapsed between breaking of the two wires; and now—knowing this interval of time, and knowing also the distance between the two wires, we can calculate at once the velocity of the projectile in going from one wire to the other.

Within the past few years, electricity has come to be employed to a great and increasing extent in firing great guns both in ships and in forts.

In the case of ships, the advantage of electrical firing lies in the fact that a gun can be fired more quickly by electricity than by other means. The ordinary means of firing are, as is well known, percussion and friction, and in each of these systems the moving parts have to be of such strength that considerable force must be exerted by the arm, in order to operate them; moreover, for prudential reasons, the line leading to them from the hand must be kept very slack, lest a lurch of the ship should cause such a movement of the man's body as to bring a strain on the line sufficient to cause the accidental firing of the gun. Therefore, when the gun captain finds the sights on the gun bear on the target, he must then move his arm through a considerable distance and exert considerable force before the gun will be fired. It may seem as if the time were insignificant, but when it is considered how rapidly a ship rolls, and how swiftly a modern ship moves, and when it is remembered how small an error in the elevation of a gun suffices to make a projectile fall short of, or go over, a ship which subtends a very small angle in a vertical plane, it will be seen that a fire which comes instantaneously with the coincidence of sights and target, is better than one which does not. Now, in firing by electricity the gun captain holds a sort of push-button in his hand, which he simply presses, when the sights bear on the target; and practical experiments abroad have shown that greater accuracy is attainable by this method than is attainable by the old methods. But not only are modern vessels of war fitted with means for electrically firing individual guns; they are also fitted with means for

firing any desired number together, the whole broadside even; for the effect upon an enemy of a blow from a whole broadside at once, is very much greater than the effect of the same number of guns fired at different times.

The simplest way of doing this, is to lead the electrical wires from all the guns to an armored fighting tower, where a cool officer under the personal direction of the commander, with an electrical key-board and a good system of sights, can deliver the whole fire of the broadside at once upon an enemy.

This officer being clear of the smoke and away from the excitement and bustle of the battery and with a view of the whole horizon, can clearly handle a battery with its maximum effectiveness; and, moreover, as soon as the guns have been laid at the range and in the direction at which it is intended to fire them, the men can lie down and be protected in a measure from the murderous fire of machine guns. Suppose that two modern ships are about to engage in a naval duel on the high seas, and that they are advancing towards each other at a speed of fourteen knots an hour each, so that they are coming together at a rate of about forty-six feet per second. The ships will of course begin to play on each other with their machine guns as soon as they get within range, so that as soon as the great guns are ready, the men had best be made to lie down on the deck in rear of them.

Now, the battery of each ship will probably be composed of guns firing projectiles of from 100 to 1,000 pounds, and each commander knowing how much damage can be done by one well-delivered shot, knowing how long it takes to reload a modern gun, and appreciating the great speed at which the ships are approaching, will probably reserve his fire until sure that he has a good chance of making every shot tell. He will hardly fire at 2,000 yards range, knowing that his chance of hitting the rapidly moving target is small, and knowing that it will be only about one minute before the enemy will be at 1,000 yards range. Now, at 1,000 yards range, the machine guns of both ships will be working vigorously, and each ship will have an excellent target, but a target improving so rapidly that a commander will not wish to throw away all the shot of his great guns until a closer range is reached. One gun, for instance, might be fired now, having been previously, of course, laid for this range; but probably it would be

best to reserve nearly the whole broadside to be delivered simultaneously as the ships rush by each other at pretty close range. With the heavy guns and carriages of the present day, it would be impracticable to keep a gun pointing at a ship under these circumstances, since both range and bearing are changing so rapidly; therefore, the guns must be pointed in certain directions, and laid for certain ranges, and fired when the enemy reaches the spots thus defined.

In the case of a fort, the value of firing by electricity is evident, since it can be employed in connection with the instruments used for determining at each instant the position of an approaching vessel or army. Different guns being laid at different ranges, and in different directions, an officer in the operating rooms can keep track of the exact position of the enemy, and when the enemy reaches one of the predetermined points, all he has to do is to touch an electric key and fire the gun, or guns, controlled by that key, knowing that those guns are not only pointed in the proper direction, but also are elevated for the correct range. It would seem difficult to improve upon the accuracy attainable by this method.

Whitehead torpedoes are now so arranged that they can be ejected by pressing an electric button; and the firing key-board in the fighting tower of a ship indicates at any instant what guns and torpedoes are ready for firing. The fighting tower should also be fitted with engine and steering telegraphs, and indicators for showing whether the commander's orders to the engine and steering apparatus have been understood and executed, so that the commander can tell at a glance the exact state of affairs at battery, engine and steering apparatus, and can have all the separate departments of his ship under his personal control.

Within the past three years the superiority of the incandescent electric light over all other forms for ship use has become more and more evident; and now nearly all first-class merchant steamships launched and all men-of-war are fitted with electric lights. In men-of-war, this light has even more advantages than in merchant ships, by reason of its safety in illuminating magazines, shell-rooms, torpedo store-rooms, etc., and the ease and speed with which it can be used in signaling at night.

For some time the electric light was declared unsuitable for naval use, the reason being urged that if the wire carrying the

current should be shot away in action, the whole ship would be plunged into darkness, and that the same thing would happen if any accident should befall the dynamo generating the current. The answer to this very sensible criticism is that, (1.) different circuits must be arranged for different parts of the ship, so that an accident in any part of the ship will affect that part only; (2.) that the wires carrying the current must be arranged in duplicate, so that even in case one wire is shot away the light will burn as brightly as ever, since the other wire remains, and is of sufficient size to carry all the current; (3.) it is very easy to repair a break in a copper wire, even if it be shot away, the only thing necessary being to bridge over the break by a wire a few inches long whose ends can be clamped, spliced or even twisted on to the broken conductor on each side of the break. As to the danger to be feared from accident to the dynamo and engine, this can be guarded against in two ways: (I.) By placing the dynamos and engines in a place as well protected as that occupied by the main boilers and engines of the ship, preferably near the engines, below the water-line and under a protective deck, and this place should be provided in laying down the original plans of the ship. (II.) By not placing dependence on one dynamo and engine alone, but by dividing the total work among three or four, so that in case of accident to one, the ship will have the benefit of all the others. To this end all the dynamos should of course be of the same electro-motive force, and feed into the same mains from which all lamps draw their supply, and which are fed by feeders from the dynamos at different points, so that accident to the mains in one part of the ship will affect that part of the ship only. But it is the arc light, used as what is called a search-light that is most valuable in warfare; a search-light being simply a very powerful arc light so arranged with a catadioptric mirror, that it throws out a very concentrated beam of light, and so mounted that this light can be cast in any desired direction, and made to illuminate any locality which it is desired to inspect. I believe the first use made of search-lights was in the siege of Paris in the Franco-Prussian War, when the French employed them to discover the operations of the besieging army at night. Their value from a military point of view was so evident that other nations took the hint and introduced them into their military and naval services. Since then

their use has been extending, more, probably for ship use than for use on shore, though they are employed considerably also in forts guarding the approach to harbors, to watch for the approach of hostile fleets, torpedo boats or countermining expeditions at night.

For the use of an army in the field, search-lights are mounted on suitable wagons together with portable boilers and engines, so that they can be taken on the march, moved to any part of the field, the top of a hill for instance, and employed at night whenever desired. It is clear that a search-light might often be very useful in doing such work as searching for wounded after a battle, examining the nature of the ground in a comparatively unknown country, watching the enemy when a surprise might be anticipated, guarding against a sortie from a beleaguered fort or city, etc., on many occasions; in fact, when the darkness of the night might be a hindrance to the operations of an army, or an element of insecurity.

On board men-of-war, the principal use of the search-light has been in watching for the attack of torpedo boats; but the experiments in Bantry Bay last July, showed that it was often useful in detecting the approach of hostile ships, in aiding the sighting of guns at night by bringing the target out clearly, and in embarrassing the operations of a torpedo boat or ship in trying to force a passage up a channel by dazzling the eyes of the enemy one instant and leaving them in total darkness the next.

It was related that in Africa, some three years ago, an attack on a fort was frustrated by a single search-light. The barbarians advanced to the assault brave and determined under cover of darkness, but were suddenly terrified by finding themselves enveloped in an aweful and miraculous light, which turned night into day. Halting for an instant, they covered their eyes to shield them from its dazzling whiteness; then suddenly turned and fled in panic.

But even had they not been barbarians, even had they been trained soldiers of a highly civilized people, how bewildered they would have been to find themselves suddenly in such a brilliant light that their eyes were blinded so that they could not see to pick their way; and then in a few seconds, just as the pupils of their eyes had contracted under the influence of the light, to find themselves suddenly in total darkness! Such alternations of

dazzling light and black darkness would render the march of an attacking force over a broken country towards a fort a very difficult undertaking; for it should not be forgotten how dependent we are upon our eyes, for our most simple actions, and how much our eyes assist us even in the dark. It may be pointed out here, that the search-light, like all other military instruments, must be used with judgment. It should not be used for instance, when it is important to keep your position secret from the enemy, unless the advantages of observing him outweigh the disadvantage of disclosing your own position; or unless you can immediately extinguish your light, and change your position. In order to use the search-light effectively on board ship, there should be four on each side of the ship. Search-lamps are of much higher power than any other lamps that have ever been made, and the effect of the white cylinder of light, as it touches up the different points of the land or sea over which it is made to rapidly pass, is striking and beautiful in the extreme. The people of Philadelphia may remember the naval search-light, which I used to illuminate the city last autumn, and do not have to be assured of its power and beauty. The best idea that I obtained of its illuminating effect was had one night, when I went to the tower of the Pennsylvania Railroad Depot, and watched the light stationed at the Electrical Exhibition building, on Thirty-second Street. The ray of light, when turned at right angles to my direction, looked like a silver arrow going through the sky; and when it was turned on me, I could read the fine print of a railroad time-table at arm's length.

For signaling at night, incandescent lights and search-lights both have been used, the search-lights being employed to reach long distances, or to reach points hidden by hills or other intervening objects. In using the search-light in this case, the beam is thrown into the sky, and signals are made by showing long and short flashes, or by interrupting the beam in accordance with any preconcerted code. Flashes from the search-light, which I had at the Electrical Exhibition last autumn, were seen from a distance of thirty miles.

In using incandescent lamps for night signaling, the simplest way is to arrange a key-board with keys marked with certain numbers, indicating the numbers of lamps arranged in a prominent position, which will burn while that key is being pressed. If it be

desired to signal the number 5348, for instance, meaning, let us suppose, "prepare to receive a torpedo attack," it is only necessary to press in succession keys marked 5, 3, 4 and 8, and the light of 5, 3, 4 and 8 lamps will successively blaze out and expire. Other codes, of course, can be used; the Morse code, for instance, in which a dash can be denoted by two lamps and a dot by one. One lamp could, of course, be used; the dot being denoted by a short flash, and a dash by a long flash, but it is found best practically not to use time intervals in optical telegraphy.

Electric lights have been used considerably of late in photographing the bores of great guns. Views can be thus obtained of any part of the bore, showing whether the gun has been accurately bored and rifled, and showing how the metal is standing the erosion of the powder gases.

One of the needs arising in modern warfare is means for handling heavy ordnance with speed and precision, and for bringing up ammunition. Guns, carriages and ammunition have increased so much in weight, that it has become more difficult to handle them quickly than it used to be, and yet the speed of ships has so increased that there is more necessity for handling them quickly. The electric motor will certainly be used for handling ordnance on board ships not very heavily plated with armor, for it is clear that a small wire is a much more convenient way of conveying energy to a motor of any kind, and is much less liable to injury in action than a comparatively large pipe for conveying steam, compressed air, or water under pressure; and, besides the electric motor is the ideal engine for work on board ship by reason of its smooth and silent motion, its freedom from dirt and grease, the readiness with which it can be started, stopped and reversed, and its high efficiency.

Col. Hamilton, U. S. A., says that in forts heavy guns must be worked by dynamo-electric machinery, since some other power than manual power must be employed, and since electricity is better than steam, compressed air, or water under pressure, because it can be conveyed from a central source by a single wire. Now in forts it is clear that the dynamos for search-lights, and incandescent lights and for generating power for the electric motors for handling the guns, could be placed in a well-protected spot, and the wires leading therefrom could pass to the guns through under-

ground pipes where they would be well protected from projectiles; and the guns could be pointed in any desired direction with speed, silence and precision by the simple turning of a lever or the moving of a switch.

It is probable that in the near future every man-of-war and every fort will be fitted with a complete "electrical system," well-protected from projectiles, which will include dynamos capable of supplying a very large amount of electrical energy to a system of mains, from which all the incandescent lights, all the search-lights and all the motors of different sorts can draw the supply of energy requisite for their needs.

Electrical launches have been tried abroad to some extent, and with results which, though not completely satisfactory, give promise of success in the future These boats are propelled in the same way as other boats; that is, by a propeller revolved by an engine, except that the engine is an electrical engine instead of a steam engine, the electrical engine drawing its power from what are called storage batteries carried in the boat. These storage batteries are first charged by a dynamo ashore or on board ship, and then are capable of rendering up to the motor the electrical energy stored in them, so that the motor is made to revolve and thus cause the revolution of the propeller and the advance of the boat through the water. These electrical launches have carried hundreds of persons, and have made a speed of about eight knots per hour, and the electric engine has worked perfectly well, but there has been considerable trouble with the storage batteries. Now these storage batteries are improving every day, and as their defects do not now seem irremediable, and as many electricians are devoting study and experiment to them, we may hope that storage batteries will soon be efficient and durable. This done, the electrical launch will certainly replace the steam launch in warfare, by reason of the quickness with which an electrical launch can be got ready, as there are no fires to be lighted and above all by reason of the noiselessness of the electric motor, and of the fact that in an electrical launch no flame ever flares up above a smoke pipe. With steam torpedo boats this flame frequently betrays them; that is, if the noise of the exhaust has not already done so. In using electrical launches in warfare, two sets of storage batteries will of course be necessary, so that one set can be replaced by another, and used while the first set is being recharged.

A novel application of electricity has recently been made in what have been named "electric sights." It is well known that it is difficult to get a sight at an object in the dark; (1.) because the object itself cannot be distinctly seen, and (2.) because the front sight of the gun cannot be distinctly seen. Now M. Gaston Trouvé has recently invented an electric sight no larger than the ordinary front sight of a musket, which consists simply of a filament of fine wire in a glass tube covered with metal on all sides save at the back. It looks much like an ordinary sight except to a man looking along the barrel towards the back of the lamp. But a man so looking, sees a fine incandescent wire. The battery is said to be no larger than a man's finger, and to be attached to the barrel near the muzzle by simple rubber bands, so arranged that the act of attaching the battery to the barrel automatically makes connection with the sight; and so arranged also that the liquid of the battery is out of action except when the musket is brought into a horizontal position for firing.

To throw a good light upon the target, the same inventor has devised a small electric lamp and projector, which is placed on the barrel near the muzzle by rubber bands, the battery being held at the belt of the marksman, with such connections that the act of pressing the butt of the musket against the shoulder completes the electric circuit, and causes a bright cylinder of light to fall on the target, thus bringing it out into strong relief and enabling the marksman to get as good a shot as in the day-time.

An application of electricity coming somewhat into use abroad in Continental armies is in connection with ballooning, which has received there the benefit of considerable attention and experiment. It is well known to all here that balloons have been much used for observing the movements of the enemy from a distance, and now it is reported that not only have balloons been successfully fitted with telephones for communicating at once to persons on the ground the nature of the information gathered, but also with small search-lights by which the ground can be illuminated for a considerable distance at night and the enemy's manœuvres discovered.

Incandescent lamps have also been sent up in small translucent captive balloons and under small ordinary captive balloons, and signals have been transmitted to a distance by making and breaking the current according to a preconcerted code.

Still another way in which electricity will undoubtedly be used in any future war between civilized powers, is, in boats which go beneath the surface of the water, to attack ships below the water-line. Though it cannot be said that submarine boats have ever yet been successful, still they are being improved and men have always been found willing to risk their lives in them. Some have been devised of late years in which the propelling power is electricity derived from storage batteries. In submarine diving, the telephone has been used with success in maintaining constant communication between the diver and his attendants above water, and the incandescent lamp suitably protected has also been lowered into the water to light him at his work. Submarine diving will certainly play a part in future wars, the diver descending to cut an enemy's torpedo-cables, or to inspect or repair damages to submarine wires or to ships.

Progress has been made in what have been christened "electrical guns," in which the cartridge contains an electric fuze which is ignited by pressing an electric push-button on the gun, instead of containing the ordinary percussion primer, which is struck by a hammer or bolt when the trigger is pulled. At present, this invention has not reached the practical stage, and the necessity for a battery to fire the cartridge is decidedly an objection. Yet we should remember that the battery required is very small, that it needs very little care, and that it will last a long time. We should also note that an electric gun possesses the great advantage that a better aim can be got with it than with one fired by a trigger, for the reason that the hard pull of the trigger causes a movement of the barrel, except in the hands of the most highly skilled marksman. Now, this hard pull of a trigger is a necessity, since the hammer or bolt must have considerable mass, in order that it may be strong enough to strike the primer with sufficient force to explode it; and having considerable mass, it must have necessarily considerable inertia, so that it needs a deep notch in order to hold it firm at full cock when jarred, and this deep notch necessitates a strong pull on the trigger. But with an electric gun, the circuit-closing parts can be very small and light, and can be put into a recess in the butt of the gun, out of the way of chance blows, so that when it is desired to fire, a very light pressure of the finger is all that is needed, and yet from the small inertia of

the parts, a sudden shock will not cause accidental closing of the circuit and firing of the gun.

We have now taken a running survey of the uses of electricity in war, and we find that they include nearly all the uses to which electricity can be put. Warfare now means more than the mere handling and provisioning of troops and ships; it means in addition the intelligent employment of scientific instruments. Particularly is this the case with naval warfare, for a modern ship, considered as a whole, is in itself the most elaborate, complicated and powerful machine existing.

Science has made warfare a greater thing than scientists themselves foresaw, for, it has put into the hands of our naval and military commanders, weapons surpassing in power and length of reach the fabled weapons of mythology. Yet our wonder and admiration at what has been accomplished pale before our wonder and admiration at what will surely be accomplished. Progress is marching with rapid steps. Looking forward to the future with the light the past affords us, we see the promise of great things to come. Let us welcome each new triumph of the discoverer and inventor, and take advantage of every resource that science can suggest. War is a sad necessity, but it comes seldom to a nation known to be prepared. Let us thoroughly prepare ourselves, then if war does unfortunately come, we need not fear the issue.

DECOMPOSITION OF DIDYMIUM.—Dr. C. A. von Welsbach appears to have discovered that the "dyad or triad element" didymium with an "atomic weight" of 48, or 96, or 147, according to the text books employed, and which since its separation by Mosander, in 1841, has been investigated by Marignac, Hermann, Watts, Bunsen, Deville and Erk, not to mention many others, is no element at all, but is built up of two substances, which can be separated from each other by an ordinary chemical process. The "decomposition" was in fact effected by means of the double ammonium or sodium nitrates in presence of lanthanum salt. The colors of the salts of the two substances are quite different. The salts of that which approaches lanthanum in its chemical characteristics are of a leek-green, those of the other substance are rose, or amethyst red, and it is this substance which exists in greatest quantity in didymium. Dr. von Welsbach proposes for these two new substances the names of "praseodymium" and "neodymium." It will be readily seen that from the chemical point of view alone these results are of very high interest.—*Chem. Zeitung; Nature, Sept. 10, 1885.*

COAL-TAR DISTILLATION.

BY PROF. SAMUEL P. SADTLER.

[*A Lecture delivered before the* FRANKLIN INSTITUTE *January 11, 1886.*]

To the mind of the superficial or uneducated man, coal suggests only a most convenient and compact form of fuel. He may be aware that there are some differences in the several varieties that meet his observation, but probably knows only that one is more compact than the other, or that one burns less freely than the other. But the chemist, or the man of practical education, recognizes a wide reaching and fundamental difference. Leaving out of sight the theories as to the origin of coal and the successive stages in the alteration of the original vegetable tissue, he knows that a coal, with a large percentage of its carbon combined with hydrogen in the form of volatile hydro-carbons, is a very different material, both in its behavior and its possibilities, from the coal which contains little volatile matter, and whose carbon is what is known as "fixed carbon." In other words, he knows the distinction between bituminous and anthracite coal, and can at once decide in a general way at least on the possible industrial applications of each.

Let us confine ourselves for this evening's discussion exclusively to the former, and to some of the industries both present and prospective that connect themselves with it. Bituminous coal (using the word in the widest sense to include all coals having over about twelve per cent. of volatile matter) may be used, without treatment, as raw coal for fuel in domestic use, or, in the case of certain varieties, even in the iron blast furnace, but by far the larger amount is heated in some sort of retort or oven, out of access of air, with a view of driving off its volatile matter and leaving the fixed carbon, which is then known as coke. This process is termed "destructive distillation." It may be carried out with primary reference to the solid residue of the process, as in the making of coke for metallurgical use, or with reference to the collecting of the gaseous portion of the volatile matter, as in gas works. As yet, the condensable portions of the volatile matter are only obtained as side-products, or "residuals," in connection with the production of one or the other of the two materials, the gaseous, or the solid pro-

ducts. In this country, indeed, only in connection with the production of the gaseous products of the distillation.

It is of this third class of products of the destructive distillation of bituminous coal, much more complex and, perhaps, for that reason much less known than the other two classes, that we wish particularly to speak this evening. This mixture is known collectively under the name of "coal-tar." That it is a complex mixture, I have already stated. That it is a very variable mixture, may also be averred with entire safety. This will be readily understood when we come to look at the wide variation in the composition of the crude material which is submitted to distillation, viz., the different varieties of bituminous coal, and consider also the varying conditions as to temperature, method of applying heat, size and shape of retorts, admission or perfect exclusion of air, and perfection of condensing apparatus under which distillation may be carried out.

Before speaking of the processes of distillation and the characters of the tars obtained, it will be well to set before us the composition of some of the best known and most extensively used varieties of bituminous coal. The following tables show some of the typical American gas coals, coking coals, and non-coking or block coals. The analyses are taken largely from the publications of the Second Geological Survey of Pennsylvania:

I. Gas Coals.

	Westmoreland Coal Co.			Penn Gas Coal Co.		
	South Side Mine.	Foster Mine.	Larrimer, No. 2.	Irwin, No. 1.	Irwin, No. 2.	Sewickley.
Water at 225°,	1·410	1·310	1·560	1·780	1·280	1·490
Volatile matter,	37·655	37·100	39·185	35·360	38·105	37·153
Fixed carbon,	54·439	55·004	54·352	59·290	54·383	58·193
Sulphur,	·636	·636	·643	·680	·792	·658
Ash,	5·860	5·950	4·260	2·890	5·440	2·506
	100·000	100·000	100·000	100·000	100·000	100·000
Coke per cent.,	60·935	61·590	59·255	62·860	60·615	61·357
Fuel ratio,	1 : 1·47	1 : 1·48	1 : 1·38	1 : 1·67	1 : 1·42	1 : 1·56
	McCreath.	McCreath.	McCreath.	McCreath.	McCreath.	McCreath.

II. Coking Coals.

	Connellsville, Frick & Co	Bennington, Cambria Iron Co.	BroadTop, Barnet.	BroadTop, Kelly.	Cumberland.	Huntingdon Co., Alloway Colliery.
Moisture,	1·260	1·400	. . .	. . .	1·10	·250
Volatile matter,	30·107	27·225	16·00	19·68	15·30	14·510
Fixed carbon,	59·616	61·843	74·65	71·12	73·28	77·042
Sulphur,	·784	2·602	1·85	1·70	1·23	1·338
Ash,	8·233	6·930	7·50	7·50	9·08	6·860
	100·000	100·000	100·00	100·00	100·00	100·000
Coke, per cent.,	68·63	71·375	81·	78·	83·59	85·24
Fuel ratio,	1 : 1·98	1 : 2·27	. . .	. . .	1 : 4.78	1 : 5·30
	McCreath.	McCreath.	T. T. Morrell.	T. T. Morrell.	McCreath.	McCreath

III. Non-Coking Coals. (Block Coal.)

	Mercer Co., Pa., Sharon Coal.	Youngstown, O.	Mercer Co., Pa.	Straitsville, O.	Brazil, Ind.
Moisture,	3·79	3·60	3·80	. . .	. . .
Volatile matter,	35·30	32·58	25·49	36·50	40·15
Fixed carbon,	53·875	62·66	68·03	55·60	57·20
Sulphur,	·675	(·85)	1·04	·96	·75
Ash,	6·36	1·16	1·70	6·94	1·90
	100·000	100·00	100·06	100·00	100·00
Coke, per cent.,	60·91	. . .	. . .	61·	58·
	McCreath	Wormley	Jno. Fulton	Wormley	Prof. Cox

It is unfortunate for the full discussion of the result of destructive distillation, as applied to these coals, that the percentage of nitrogen was not determined in all these cases, but it probably ranges between 1·3 and 1·6, and would perhaps average 1·5 per cent. An ultimate analysis of the Hocking Valley block coal, taken from the Geological Survey Report of Ohio, gives the following figures:

Carbon,	77·88
Hydrogen,	6·56
Nitrogen,	1·51
Oxygen,	10·57
Sulphur,	0·64
Ash,	2·84
	100·00 (Lilienthal)

Ultimate analyses of English coals will be given later on. Now, as to the effect of destructive distillation upon crude materials of the composition just shown. If we take what are distinctively called gas coals, their composition is not very widely different. Are the products of the distillation of coal, therefore, uniform? With regard to the solid residue, fairly so. The coke does not differ notably when the distillation has been carried to completion. With the gaseous products, there is much more difference, both in composition and amount obtained. But, with the liquid or condensable products, the results are the widest in their divergence. Probably the chief factor in producing the differences is heat. To understand this, a brief consideration of the chemical principles involved in the decomposition of the crude material and the formation of the best known of the products obtained is desirable.

From a most valuable monograph upon "Destructive Distillation," by Prof. Edmund J. Mills, of Glasgow, the following fundamental statements of theory are taken: "The process of decomposition by means of heat is most completely realized in the sun's atmosphere, which consists of the resolved weights of our common elementary and perhaps some more simple bodies. At the next lower temperature, that of the voltaic discharge, hydrogen unites with carbon to form acetylene, and with oxygen to form water. From these two products, most organic bodies can be obtained by synthesis; benzene, for instance, by keeping acetylene for a long time just below a red heat; naphthalene, by passing a stream of benzene, or one of its homologues, through a red-hot tube; ethylene, by hydrogenating acetylene; alcohol, by hydrating ethylene. Hence, naphthalene, hydrogen and acetylene, with less benzene, are found in coal-tar products when a very high temperature is used; at a red heat, they are absent, more benzene and chrysene being found. At a very high temperature, the products from coal

and shale are carbon and carbonized gases of low illuminating power, with but little liquid distillate; at a low temperature, there is much liquid product and gas of high illuminating power. The greatest amount of liquid product of low-boiling point is found in American and Russian petroleums, which have probably been produced by the long-continued application of a very gentle natural heat."

To show the verification of these principles in practice, the results of high and low temperature distillation upon the same gas coal, may also be quoted from the same authority:

		High Heats.		Low Heats.	
VOLATILE MATTER.	Gas,	20·49		6·49	
	Ammonia water,	3·09		7·24	
	Tar or oil,	17·08		26·45	
	Sulphur,	0·29		...	
	Water, at 212°,	4·15		...	
			45·10		40·18
COKE.	Fixed carbon,	45·00		49·93	
	Sulphur,	0·34		...	
	Ash,	9·56		9·89	
			54·90		59·82
			100·00		100·00
PRACTICAL RESULTS.					
Gas per ton of coal at 60° F., and 30 in. Bar.,		10·415 cub. ft.		3·800 cub. ft.	
Illuminating power in standard candles by union-jet consuming 5 cub. ft. per hour at 5 inches pressure,		31·75		...	
Gravity of gas-air, 1,000,		·574		...	
Gallons of crude tar per ton of coal,		...		63·44	
Specific gravity of crude tar oil,		...		0·934	
Gallons of ammonia water per ton of coal,		...		16·12	
Pounds of sulphate of ammonia per ton,		...		1·54	

NOTE.—The low heat results were gotten by distilling the sample in a two-inch iron tube in a gas furnace.

Now, confining ourselves again to the tar or condensable product, does the composition of it, when considered in detail, vary less than does the relative amount produced? The normal constituents of an ordinary gas tar, which we may reasonably characterize as a high temperature tar, are shown from the following examples:

The average quantitative composition of London and Berlin gas tars is given on the authority of Schultz,* as follows:

LONDON GAS TAR.

Benzol of 50 per cent.,	1·1
Solvent naphtha,	1·0
Burning naphtha,	1·4
Creasote oil,	33·2
Thirty per cent. anthracene,	1·0
Pitch,	58·6
Loss,	3·7
	100·00

BERLIN GAS TAR.

Benzol and toluol for anilines,	0·8
Bright (solvent) oil,	0·6
Crystallized carbolic acid,	0·2
Creasol (disinfecting quality),	0·3
Naphthalene,	3·7
Anthracene (pure),	0·2
Heavy oil (for impregnating timber)	24·0
Pitch.	55·0
Water and loss,	15·2
	100·00

Tars such as these are gotten in the ordinary course of gas making, where the temperature averages 2,000° F. How is it in low temperature tars? Unfortunately, no analyses of the low temperature tar quoted before from Mills is given. We must take then the Jameson coke-oven tar, to be spoken of later, as our typical low temperature tar. Dr. Watson Smith, who has given it a thorough chemical study, states† that benzene is quite absent from it, although, in admixture with paraffins, both very small quantities of toluene and larger quantities of xylene are present, as he obtained their nitro-products; that in its light fraction, "the bodies present belong to the marsh gas series mainly;" that "the chief bulk of the Jameson tar, having a sp. gr. of 0·960, consists of oils boiling between 250° C. and 350° C., from which on cooling no crystalline substance separates;" that "a considerable proportion of oil distils over above 350° C., viz., from somewhere above 400° C. to

* Schultz, Chemie des Steinkohlentheers, pp. 95 and 96.

† Paper read before British Association, at Southport, September 24, 1883.

the point at which pitch remains in the retort, and these oils separate paraffine scale and the paraffine wax obtained has a high melting point, viz., 58° C." Again, "if the crude oils boiling between 200° C. and 300° C. be treated with caustic soda lyes, and the phenols extracted in the usual way, a fairly large proportion of a peculiar series of phenols of increasing boiling points is obtained in the crude extract, certain of these phenols resembling the constituents of the creasote of wood-tar. A mere trace of carbolic acid was found, but more of the cresols, and by far the largest bulk of the constituents of the crude phenol distils at from 250° C. to 300° C. The latter fraction, boiling at about 300° is a resinous substance perfectly soluble in caustic soda, to which it communicates a red color." "Neither naphthalene nor anthracene are present, even in traces, in Jameson's coke-oven tar." "The fact that the specific gravity of this tar is less than that of water is a circumstance sufficient of itself to indicate that it belongs to the class of tars obtained by the distillation of coal at lower temperatures."

With this low temperature tar may also be contrasted a high temperature coke-oven tar. Such is found in the Simon-Carvés tar, to be spoken of, too, later. The temperature here even rises beyond that of the gas retorts, being 2,200° F., and with the newer recuperative ovens 3,000° F. Watson Smith *(loc. cit.)* finds that "the Simon-Carvés tar is quite different both in appearance and specific gravity from Jameson's; its specific gravity is 1·20, and it is black and thick and smells quite differently from the Jameson product; the former therefore sinks at once in water, whilst the latter floats on the surface. In composition, the tar from Carvés ovens closely resembles the tars produced in the large London gas works, *i. e.*, it is exceedingly rich in naphthalene and anthracene, but less rich than some, *e. g.*, the Lancashire tars in benzene, toluene, xylene and carbolic acid; but these it contains as richly as any London tar. It is, moreover, quite free from paraffine. This great difference in the Simon-Carvés tar from that of Jameson is due to the fact, that in the production of the former, a close oven, a very high temperature, and a rapid distillation are adopted, just as is the case in the gas works.

A second very important factor in determining the results of destructive distillation, inferior only in value to that of temperature,

is the presence or absence in the retort or oven of large surfaces of incandescent porous solids, such as coke or firebrick. These, taken in connection with high temperature, seem to have a very great influence in determining the formation of such constituents as naphthalene and anthracene. Thus Atterberg, (*Berichte*, 1878, p. 1222), passed Swedish wood-tar through iron tubes *filled with coke*, heated either to dull or to bright redness. The product obtained at a bright red heat contained all the essential constituents of coal-tar, it was rich in naphthalene, contained a fair amount of anthracene, but only small quantities of phenols, and about seven per cent. of benzene and toluene. At a dull red heat, fifty to sixty per cent. of the tar escaped unchanged; naphthalene could not be discovered in the product and only 0·3 per cent. of anthracene was detected by the chromic acid method; ten per cent. of toluene, containing but little benzene, was obtained and higher phenols, with but little phenol itself. Letny, (*Berichte*, 1878, p. 1210), whose results were published in Russian, in 1877, made experiments on a large scale in a retort 7 feet long and 1 foot across, with Baku petroleum residues (sp. gr. 870; boiling point, 270° C.) which were led over red-hot charcoal. Tar, equal to about forty per cent. of the petroleum, was obtained of the following composition (sp. gr. 1207):

Below 200° C.—13·9 per cent.	2·3 per cent. water. 4·6 per cent. benzene below 90° C 5·2 per cent. toluene, etc., 90°—145° C.
From 200° to 270°—26·9 per cent. From 270° to 340°—8·6 per cent.	Naphthalene and unchanged petroleum.

The portion boiling above 340° C. was collected in three fractions.

(*a.*) 12 per cent.	9·3 per cent. petroleum. 2·7 per cent. crude phenanthrene. ·76 per cent. pure phenanthrene.
(*b.*) 7·5 per cent.	5·2 per cent. petroleum. 2·4 per cent. crude anthracene. ·8 per cent. pure anthracene.
(*c.*) 8 per cent.	6·04 per cent. petroleum. 1·94 per cent. crude anthracene. 1·5 per cent. pure anthracene.

Besides tar, a mobile liquid was obtained, consisting of benzene, toluene, xylene, and naphthalene, almost free from bodies of higher boiling point. Letny therefore attaches great importance to the presence of porous carbon, and states that the quantity of solid hydrocarbons produced is greater in proportion as the layer of car-

bon through which the vapors must pass is thicker. Letny's process was carried out later on a large scale at the Ragosine refinery at Kasan on Russian petroleum residues, and by the firm J. G. Geigy, of Basel, on American petroleum residues in their branch factory at Cleveland, O., and samples of the benzene and anthracene from this source were exhibited at the Swiss National Exhibition, at Zurich, in 1883. The firm of Nobel Brothers, the great Russian petroleum producers and refiners have also carried out on a large scale similar experiments and get from *astatki*, or Russian petroleum residues, in one distillation, 30 to 40 per cent. of a tar containing from 15 to 17 per cent. of 50 per cent. benzene. By a second destructive distillation of the heavy oils remaining in the tar after the separation of the benzene, 70 per cent. of tar is obtained containing from 7 to 10 per cent. of 50 per cent. benzene, 16 per cent. of naphthalene, 2 to 3 per cent. of dry "green grease" (or 30 per cent. anthracene) and 24 per cent. of pitch. Having shown that the coal-tar obtained in the processes of destructive distillation may vary both as to quantity and as to quality, through quite wide limits, according to the conditions under which the distillation is carried out, let us look at methods at present in use for its production. As I said before, in no process carried out on a commercial scale is the production of the condensable liquid products of destructive distillation the primary object. They are only "residuals" as yet. As Prof. H. E. Armstrong well remarks in a recent paper,* "It is not a little remarkable that an industry of such magnitude and importance should so long have been without the chemist's guidance, especially as the progress of chemistry has received such an impetus from the study of coal-tar constituents. The distillation of coal has been left to the engineer. Attention has been directed almost solely to the production of gas. Now that other products than gas are claiming attention, it is high time that the problem should be studied in a systematic and scientific manner, and that the chemist, and not the mere analyst, should find a place in the coke and gas works." The methods of destructive distillation in connection with which the tar and ammonia water are condensed and collected, may be summarized under five heads: (1.) In the manufacture of illuminating gas; (2.) In the coking

---

* Journal of Society of Chem. Ind., Sept. 29, 1884, p. 467.

of coal; (3.) In blast furnace working with raw bituminous coal; (4.) In gas producers including regenerator and water gas methods; (5.) In the distillation of petroleum residues and the production of oil gas.

The methods of manufacture of illuminating gas from bituminous coal need not be described here. We have already spoken of the chemical principles involved and shown that the results, as far as the production of tar is concerned, may vary through rather wide limits according to the conditions of temperature, etc. The methods of separating the constituents of the crude tar of the coal gas manufacture will only be considered in their general outlines, as a detailed account of them would take up considerable space and have a special, rather than a general interest.

The crude tar, if possible, is run while hot from the tar wells direct to the stills, or if the distance does not allow of that, the crude tar is warmed in suitable vessels by coils of steam-pipe, so as to effect a more perfect separation of the tar from the ammonia water. The more of this held mechanically in the tar, the more troublesome the distillation in its first stages on account of the frothing caused by the irregular development of steam in the body of the tar. The first condensable portion, known as "first runnings," has a sp. gr. of 0·78 to 0·85, and, according to the character of the tar, constitutes from two to four per cent. On standing, this distillate separates into two layers, one of ammonia water and the other of very volatile oil (benzene spirit), which are easily separable. On strengthening the fire somewhat, there now comes over the "light oil," with a sp. gr. of 0·83 to 0·89. It amounts to from seven to eight per cent. of the tar, and consists chiefly of benzene and its homologues, but contains in addition phenol, cresols, naphthalene, and basic compounds. In those establishments, in which the distillation is controlled by the thermometer, the light oil fraction is run until 210° C. is reached. Between 210° C. and 400° C. is obtained the "heavy oil" or "dead oil," so-called, because it sinks under water. The first portions of this contains much naphthalene, so that it becomes crystalline on cooling. On farther distillation, the consistence is again thinner and finally the distillate remains liquid on cooling. It now contains phenol, cresols, and bases and hydrocarbons of high-boiling point. After a time, the oils become thick again and crystallize on cooling. This is due this time not to naphthalene, but to anthracene,

and its accompanying compounds, phenanthrene, carbazol, acetnaphthene and fluorene. The portion from 210° to 300° C. is usually caught separately under the name of "creasote oil," and that from 300° to 400° C., which is generally green colored and hardens on cooling as "anthracene oil," or *green grease*. The percentage of heavy oil of the first kind is from 32 to 35 and from 10 to 11 of anthracene oil, containing 10 per cent. anthracene. The residue of this distillation forms what is called pitch. This is run out while yet fluid and hardens to a lustrous mass, breaking with conchoidal fracture. According to the degree to which the distillation has been pushed, the pitch differs, being either soft pitch or hard pitch, known too as "carbon black." The working up of these crude fractions for the extraction of the constituents in a state of purity, we will not enter upon in this paper.

The second class of methods of destructive distillation, with accompanying tar production, before referred to, was in connection with the coking of coal. Under this head, we have to notice some results of very great interest, from both a practical and a scientific point of view. The burning of coke in pits, "meilers," or mounds, represents the first rough and wasteful method of converting bituminous coal into coke. It involves the total loss of all the volatile matter of the coal, and the pouring into the surrounding air of large amounts of black, sulphurous smoke, or the products resulting from its combustion. It allows, however, of the smothering the finished coke with fine dust, instead of requiring it to be quenched with water, as in other methods. The so-called "beehive" ovens, allow of the volatilizing of a much greater amount of the sulphur in the coal, and give a decidedly increased yield of coke over the pit-burning method. The charge can be run over, too, in less than half the time. Some air is admitted in both cases, and thus some coke is burned, and no attempt is made to save residuals in either case. In the various forms of ovens, known collectively as Belgian ovens, and including the Appolt and the Coppée ovens, no air is admitted into the coking space, but into the side flues, so as to mix with the gaseous products passing through openings in the oven walls into side flues. Thus, complete combustion of all the products is insured, and the ovens are heated thereby. No coke is burnt, the yield is therefore larger, but there is some doubt as to the quality being

as good as that from the beehive oven. The first coke ovens, that allowed of the recovery of the volatile products, were the Knab ovens, worked at St. Denis, near Paris, in 1856, and the Pauwels-Dubochet ovens, worked at Saarbrücken, in 1854. The Knab ovens were modified by Carvés, a French engineer, at St. Etienne, to whom, probably, belongs the credit of first constructing an oven for making coke with the simultaneous collection of the gas, coal-tar, and ammonia water. Passing by the many French and German patents that followed for new ovens and modifications of older ovens, looking to the collection of residuals, and referring for full information on this matter to the very elaborate historical paper, by Dr. Watson Smith, on the subject, (in the *Journal of the Society of Chemical Industry*, for December 29, 1884), we come now to the two forms of coke ovens that are at present

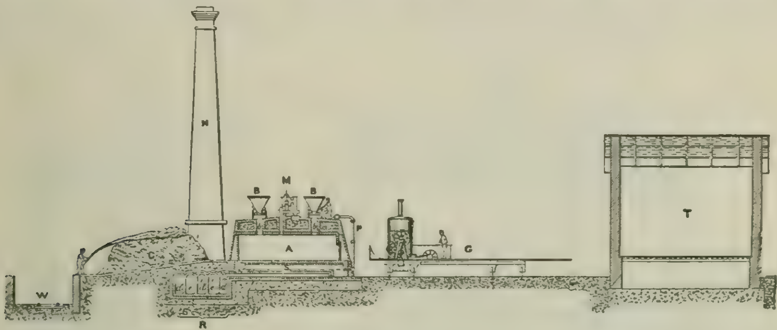


FIG. 1.

A. Coke oven.
BB. Tubs for conveying coke to ovens.
G. Steam ram for thrusting coke out of oven.
C. Coke as thrust out of oven, and man supplying water to cool it.
W. Railway where coke is put into wagons.
S. Main combustion flue.
R. Recuperator, consisting of hot air flues *d d d*, and smoke flues *e e*.
P. Pipe for return gas.
M. Main through which gases are drawn by exhauster.
T. Exhauster and pump house
H. Chimney for twenty-five ovens.

dividing the attention of practical and scientific men in England, where the subject is now more actively agitated than in France or Germany. These are the Simon-Carvés oven and the Jameson oven, both of which have now been in use on a large scale for several years.

The principles of the Simon-Carvés oven, which is the newer and improved form of the older Carvés oven, may be gathered from the illustrations in *Figs. 1* and *2*, and from the statements made by Mr. Henry Simon, C. E., of Manchester, the English patentee, in his address before the Iron and Steel Institute, in 1880. "According to our system, the coal is rapidly carbonized, by sub-

jecting a comparatively thin layer of it to a high temperature in a closed and retort-like vessel, and, whilst in the beehive ovens the volatile products are burned inside, we burn them around the outside of this retort-like vessel, and only after they are deprived of the tar and ammoniacal liquor. Each oven is in the form of a long, high narrow chamber of brick work, and a number of these are built side by side, with partition walls between them sufficiently thick to contain horizontal flues. Flues are also formed under the floor of each oven, and at one end of these is a small fire-place, consisting of a fire-grate and ash-pit, with suitable door, the fire-door having fitted above it a nozzle, through which gas produced from the coking is admitted to form a flame over some fuel burning on the grate. Only a very trifling amount of such fuel, consisting exclusively of the small refuse coke is used here, its function being really more that of

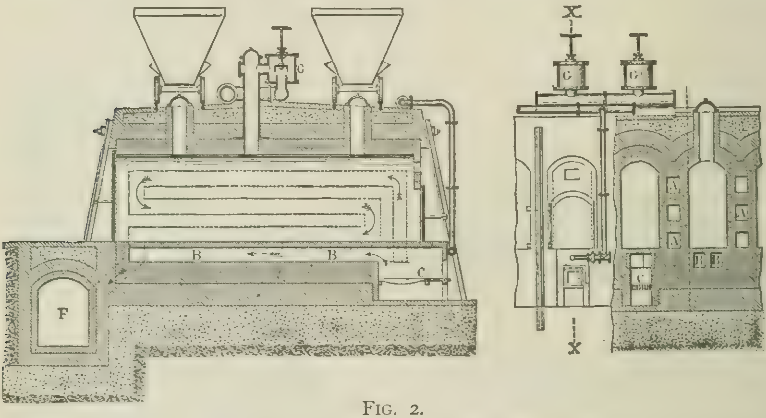


FIG. 2.

igniting the gas than that of giving off heat. These grates are not charged with fuel more than twice every twenty-four hours when in regular work. The products of combustion pass from the fire-place along a flue under the oven floor to the end farthest from the fire. They return along another flue under the floor to the fire end; they then ascend by a flue in the partition wall to the uppermost of several horizontal flues formed therein, and *descend* in a zigzag direction along these flues, finally passing into a horizontal channel leading to a chimney. Thus the coke oven is heated, not only at the bottom in the usual manner, but also evenly at the sides, and the coal with which it is charged becomes rapidly and

completely coked. No air is allowed to enter our ovens, which in reality are closed vessels, with the exception of the opening for the escape of the volatile products. The improved ovens are fed with coal by openings in the roof, over which coal trucks are run on rails; and the coal is evenly distributed by rakes introduced at end openings, provided with doors faced with refractory material, which doors are closed and kept tightly luted while the oven is in operation. The feed holes in the roof are also provided with covers. Through the middle of the roof rises a gas pipe provided with a hydraulic valve, which closes the passage by a lip projecting down from it into an annular cavity surrounding its seating, in which it is immersed in a quantity of tar and ammoniacal liquor, lodged there during previous distillations. The volatile products of the coal distillation rise by the gas pipe, and are led through a range of pipes kept cool by external wetting, so that the tar and ammoniacal liquor become condensed and separated from the combustible gas."

"The gas, when thus separated from the condensed materials, is further passed through scrubbers or vessels containing coke moistened by the ammoniacal liquor, which on being repeatedly used, becomes stronger and stronger until it reaches saturation, when it may be run off into reservoirs to be treated in the ordinary way for the preparation of ammoniaçal compounds, or sold in its crude state for the manufacture of soda by the ammonia-soda process. (All the ammoniacal liquor from the Terrenoire Works, in France, where 100 Simon-Carvés ovens are in operation, is contracted for by M. Ernest Solvay, the great manufacturer of soda by the ammonia-soda process.) All valuable bye-products having thus been withdrawn from the gas, it is led by pipes to the nozzle at the fire-places under the sole of the ovens, where it is burnt."

"When a charge is nearly finished and ready to be taken from the oven, some trucks full of coal are placed ready on the rails, going right along on the top of the ovens and over the charging holes. The two end doors are then opened. The mass of coke measuring about 30 feet long by 2 feet thick and 6 feet high is pushed out at the back of the oven and on to the bank, by means of a ram or piston worked by a portable steam engine running on rails in front. The ram can be brought opposite to each oven in turn. The coke is then quenched as usual."

A claim is made for this method of seventy-five to seventy-seven per cent. of coke to the amount of coal used. The yield of residuals, during a run of 215 days at the coke ovens of Messrs. Pease at Crook, was, on an average, 27·70 gallons ammoniacal liquor per ton of coal carbonized, and 6·12 gallons of tar per ton of coal carbonized. The selling price of the ammoniacal liquor was one pence per gallon, and of the tar three pence per gallon. The chemical character of the tar from the Simon-Carvés' ovens has been referred to already in speaking of the conditions of destructive distillation. (Sample shown.)

The Jameson process is illustrated by *Figs. 3* and *4*.

The following statement of the principles upon which it is based and of the working of the process is taken from Mr. Jameson's published papers: "The process is based upon the fact, that in the ordinary coke oven the progress of distillation and finally of

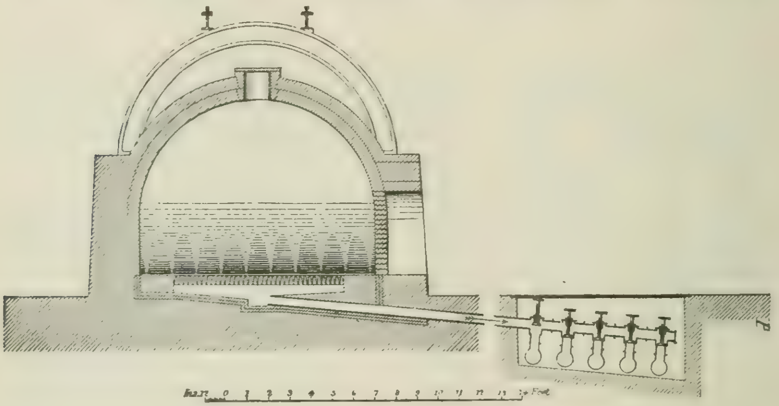


FIG. 3.

ignition of the coal operated upon is from the top downwards. If, as in the ordinary process, the products of distillation be suffered to find their way to the upper surface of the charge in the oven, the intense heat there existing and the access of air required by the process of coking at once decomposes these products and renders them valueless. If, on the other hand, the products as they are formed are caused to pass to the lower and cool surface of the charge, and are extracted from the bottom of the oven, they may be recovered quite unchanged in constitution by mere condensation. This is accomplished by making passages below the

oven floor, and laying upon these passages perforated quarles or recessed bricks, and applying gentle suction during the process of coking, by means of a pipe communicating with these passages and coupled to an exhauster."

"In the process of making coke in the ordinary oven, the rate of descent of incandescence is from half an inch to one inch per hour, and the charge of coal throughout its mass is therefore subjected in succession to a low and very gradually increasing temperature, and thus by the Jameson process the products formed at the lowest heat are obtained as they are formed, being passed immediately through the mass of cooler coal below that in which they were formed and so into the suction pipe and condenser." "An incidental effect arising in the carbonization of bituminous coal is of great importance in this view. As the coal is heated, it apparently melts together and cokes, and by this coking there is

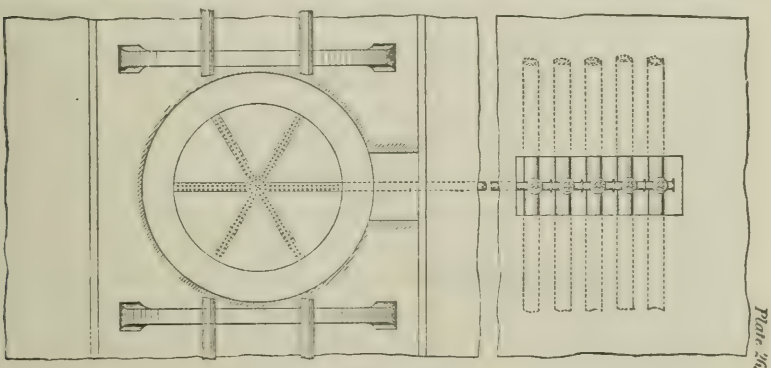


FIG. 4.

formed, at a point between the mass of incandescent coke and the raw coal, a seal or diaphragm over the whole area of the oven. Below and in the softer parts of the seal, the vapors are liberated and the harder part of the seal forms a more or less impervious shield, separating between the gases below and the gases above it, whereby, to the extent of the protection thus afforded, the one is subjected to the suction of the oven bottom, and the other is shielded from it." "Although the production of condensable products is all that can be desired, and although the incidental effect of the seal described is of great value, yet the perfection of the recovery is manifestly dependent upon the suction applied. It is clearly possible by excessive suction to break through the seal

and diminish the yield of coke, by drawing air through the charge and so burning it, and it is as clearly possible by too slight suction to make a recovery of products of almost at no value; but the range between these limits is very wide and by due proportioning of the suction with reference to the circumstances of the case it is possible to effect a large recovery of oil and ammonia with a full yield of coke of the highest quality."

The Jameson oven is in reality only an alteration of the beehive oven, involving a perforated floor, and suction pipes set in below this, and the beehive can therefore be adapted to the saving of residuals at quite moderate cost. The gas, being produced at low temperature and withdrawn as formed, is a richer burning gas than most producer gases, but the yield of coke is not so large as in the case of the Simon-Carvés' ovens, a small portion being necessarily burned at the top of the oven during the coking, because of the admission of air. The average per cent. of coke to coal used is given in a table, summarizing results during 1882–83, as 56·28, but at one set of ovens (Tudhoe Grange) an average of close on to seventy was reached. The yield of tar-oil per ton of coal coked was given by Mr. Jameson as five gallons, and of ammonia water an amount equal to three pounds of sulphate of ammonia per ton of coal carbonized. The chemical characters of the tar or oil were referred to before, in quotations from Watson Smith's chemical examination of these residuals. His results were also confirmed by Prof. H. E. Armstrong, who examined the Jameson oil. Its chief value seems to be for the production of lubricating oils, oils for oil-gas manufacture and creasoting oils.

(*To be continued.*)

SECOND BLOOMING OF CATALPA.—Mr. J. Schneck writes as follows: "On one of the streets of Mt. Carmel, Ill., stand two large trees of our local native Catalpa (*C. speciosa*, Warder). During the first week in June, they were both in full bloom. These flowers all dropped during the first half of that month. To-day, July 20th, one of them is again in full bloom. The whole top is literally covered with flowers, and, at the same time, the beans of last month's flowers are hanging thick. In this second crop, the panicles are about as large and full as in the first. The flowers are of the usual size, but a little paler. It is so unusual for a second flowering to be apparently as abundant as the first, that I think it proper to report this instance. Another peculiarity is the short time between the two crops—about six weeks.—*Botan. Gazette, Sept. and Oct., 1885.*

THE PRODUCTION OF ALUMINUM AND ITS ALLOYS IN THE ELECTRIC FURNACE.

BY EUGENE H. COWLES.

[*A Paper read at the Stated Meeting of the* FRANKLIN INSTITUTE, *held January 20, 1886.*]

W. P. TATHAM, President, in the Chair.

MR. COWLES:

Mr. President, and Members of the INSTITUTE:

In order that I may give you as brief and explicit an explanation as possible of our discovery, process and inventions, I will first proceed with a description of the plant of the Cowles Electric Smelting and Aluminum Company, now in operation at the works of the Brush Electric Company, at Cleveland, O.:

The apparatus used by us for the purpose of experiment in the reduction of refractory ores for the production of metallic calcium, magnesium, potassium, sodium, silicon, titanium, and the manufacture of aluminum and aluminum-bronze and other alloys, consists of two large Brush dynamos, two resistance boxes and two ammeters, a drying pan, eight fire-brick furnaces, suitable electrical conductors and switches, hoods for carrying off vapor and gases, large carbons—3 x 30 inches—for electrodes, screens for sizing charcoal and carbon, and a large mortar and pestle and several washing vats for washing and concentrating the furnace products. Steam-power to drive the dynamos is furnished by the "Brush Electric Company." The arrangement of the plant so as to effect the reduction of the above-named metals and metaloids, by means of carbon as the sole re-agent, is as follows:

The Dynamos.—These are, of course, placed in the dynamo room as near as possible to the driving shaft, where they can be kept free from any dust or grit from the furnace room. The larger of these is by far the most powerful machine ever built by the "Brush Electric Company." It weighs over 7,000 pounds, and at a speed of 907 revolutions per minute produces a current of 1575 ampères with an intensity of 46·7 volts. It is of the shunt-wound type of dynamo, built for the purpose of incandescent lighting;

further than being of greater capacity, and having a hub made of the Cowles aluminum-brass which exhibited a tensile strength of 95,000 pounds per square inch and five per cent. elongation, this dynamo does not differ from the ordinary machine.

Conduction of the Current of the Large Dynamo to the furnace in the furnace room and back to the machine, is accomplished by a complete metallic circuit except where it is broken by the interposition of carbon electrodes, and the mass of pulverized carbon in which the decomposition of the ore takes place. This circuit consists of thirteen copper wires each 0·3 inches in diameter. There is likewise inserted into this circuit an ampèremeter through whose helix the entire current flows, indicating, by its suction of a plunger armature attached to a spring balance and dial-faced indicator, the total strength of current being used.

This ampèremeter is an important element in the management of the furnace, as by the position of the finger on the dial the furnace attendant can tell to a nicety what is being done by the current within the furnace. It is placed upon a shelf in a good light, near to and in full view of a person in any position about the furnace.

Between the ammeter and the furnace in the furnace room, and forming part of the circuit, is placed a large resistance coil of german silver immersed in water, a heavy copper slide passing backward or forwards as desired, throwing more or less of this resistance into the circuit, and almost the entire energy of the current may be thus applied to heating water. The object of the resistance box is to serve as a safety appliance. It is used by the furnace operator when it is desired to change the current from one furnace to another, or if it be necessary to choke off the current almost entirely before breaking it by a switch, thus preventing serious flashing at the commutator of the dynamo or at the switch. It is likewise of value should any evidence of a short circuit appear in the furnace or elsewhere.

Thus far the apparatus that has been described, presents no novel feature beyond its great magnitude, the peculiar combination made, and the purpose for which it is used. Now, however, we will describe a device that we claim is something radically different from anything that has heretofore been known, namely, an incandescent electrical furnace for the smelting of refractory ores,

FIG. 1.

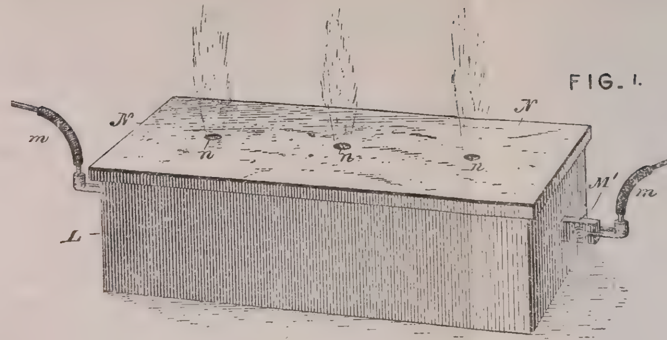


FIG. 2.

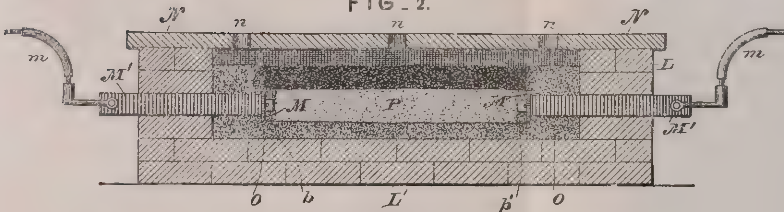
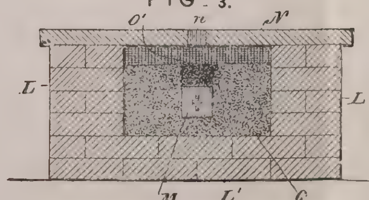


FIG. 3.



THE COWLES ELECTRIC SMELTING FURNACE.

Fig. 1. Perspective view.
Fig. 2. Longitudinal section.
Fig. 3. Transverse "
L L′. Fire-brick floor and walls.
N. Removable fire-clay cover.
n. Vents for escaping gases.

M M′. Electrodes.
m. Conducting wires to dynamos.
O. Packing of fine charcoal.
P. Charge of ore and granular charcoal.
O′. Layer of granular charcoal, covering charge on top.

metals and compounds, and in which other metallurgical and chemical operations, impossible in the past, may now be performed with both ease and economy. This furnace as constructed to utilize the current of the large dynamo, is a rectangular oblong box of fire-brick, with walls, bottom and ends, nine inches thick. The interior space being five feet long by one foot wide and one foot deep. This is closed by a cast-iron slab or cover through which are two three-inch holes for the escape of the gases liberated during the operation. This lid may be removed at will, its own weight being all that is required to keep it in place. The walls of the furnace are designed to be air-tight. At both ends of the furnace are holes large enough to admit an enormous electric light carbon, three inches in diameter and thirty inches long. Each of these carbons is connected at the end, projecting outside of the furnace, with the positive or negative conductor as the case may be, the connection being a copper cap fitting over the end of the electrode, the same being fastened to a large and flexible wire cable which forms part of the circuit. When it is desired to charge the furnace, it is first necessary to lime it, to prevent its destruction by heat. To do this, a quantity of finely pulverized charcoal that has been soaked in a solution of lime and water, and then thoroughly dried in the drying pan, is put into the fire-brick box, enough being placed therein to cover the floor to a depth of several inches. The carbon electrodes are then pushed into the box through the end walls until the ends of the carbons are but a few inches apart. These electrodes are just on top of the finely powdered charcoal of the floor. A sheet-iron gauge or guard, parallelogram-shaped, and open at top and bottom, is now placed over these electrodes in such a manner as to form two walls on either side of the electrodes about three inches distant. Space is thus left between the sheet-iron and the walls of the furnace, and likewise for about a foot at each end of the same. More finely powdered limed charcoal is put into the furnace-box so as to completely fill the space outside the sheet-iron gauge and within the furnace walls and up to within a couple of inches of the top. The furnace is now almost entirely full of the lime-washed charcoal, except the space nine inches wide, three feet long and six inches deep in the centre of the box, and into which the electrodes project. All is now ready for the charge, which is prepared. Should

it be desired to produce aluminum-bronze, we mix sixteen or eighteen pounds of granulated copper, twelve to fourteen pounds of aluminum oxide in the form of broken corundum, and several pounds of coarsely broken charcoal together, and burying the electrodes with the same. and thus filling the space inside the walls of the sheet-iron gauge. The gauge is then lifted from the furnace, additional coarse charcoal is spread over the entire mass, the iron top of box is put in place, the seams luted with fire clay, the current from the dynamo switched on, and the furnace is in operation in but little more time than it has taken to give these apparently trifling but very important details.

We will now proceed to make a little study of the philosophy of the process, after first watching a successful "run" or "heat" from the beginning to the close of the operation. Of course, the furnace and its contents, when the current of electricity was turned on, were entirely cold and the resistance presented to the flow of the current consequently is higher than it would be at any time during the "heat," unless some unforeseen accident, such as a slight explosion of gas, takes place. But notwithstanding that the furnace is cold, a complete metallic circuit, with carbon tips dangerously near together, is ready to convey a one hundred horse-power flash of lightning into the furnace, should a short circuit occur. *There are likewise many pounds of pure copper in between and about these carbon tips that may be melted and run together and thus produce a short circuit. With these conditions an electrician would insist that the man in charge of the furnace should look pretty sharply lest the four-thousand dollar dynamo at the other end of the wire be burned out, or somebody be injured by a heavy flash.* The man in charge, however, has anticipated such a contingency by having thrown in several coils of the resistance box, so that under no condition, even if the great carbons in the furnace were pressed tight together, would the dynamo be able to produce a current of more than 1600 ampères, the maximum load. Upon watching the ampèremeter, however, it is seen that this precaution was not necessary for only about 200 ampères are indicated as flowing, the artificial resistance is therefore slightly diminished, the needle of the ammeter moves up rapidly to 600 or 800 ampères, suddenly it gives a jump up to 1,200, then back to 200, then with a bang the armature of the am-

meter is brought against the magnet and it registers 1,600 ampères of current flowing, and then instantly drops back to almost zero.

As every jump of that needle means wear and tear on the commutator and brushes of the dynamo, care is now taken to keep more control of the current and a little more artificial resistance is thrown into the circuit. The needle now moves more slowly around the dial, gradually making fewer and fewer jumps, and at the end of eight or ten minutes, it has worked up to the 1,000 ampère mark, and becomes quite steady. Suddenly there is a hiss and a sharp report, a tongue of greenish yellow copper flame darts upwards from the hole in the furnace top and then disappears, to be followed after a minute or so by a slight vapor. This was caused by the monoxide of carbon combining with the atmosphere in the furnace to produce an explosive compound. To prevent this gas from accumulating to an extent to raise the furnace top and loosen the luting, the attendant holds a lighted stick over the vent and a series of slight explosions follow.

Soon a characteristic yellow-white flame appears, above the hole, the needle registers about 1,200 ampères of current flowing, all of the artificial resistance is withdrawn and the process of reducing aluminum and alloying it directly with copper is completely under way. Soon the needle gradually creeps around the dial to the 1,400 or 1,500 ampère mark. This is regarded as being a little too hot work for the dynamo and at the same time the plume of flame above the furnace indicates a little less rapid reduction. There are, therefore, two things now necessary. The first is to put more resistance into the circuit, and the second is to put more ore into the zone of reduction. These are both done by withdrawing one of the electrodes and the ammeter needle drops back to 1,200, and the flame above the furnace soon gives evidence of doing more work, by reason of more copious white fumes being given off.

This pulling out of the electrodes is repeated over and over again until both are out to their full length. At the end of an hour, the "heat" is completed. The current is then switched to another furnace, but one furnace being used at a heat. The artificial resistance is again resorted to, enough being thrown into the circuit gradually, thus slowly choking off the current, permitting the proper regulation of the brushes on the dynamo, and also

giving time for the engine to govern itself. Finally, at the end of several minutes, the switch is thrown open and the furnace is entirely out of the circuit. Furnace No. 2 is now operated in precisely the same manner as the furnace No. 1, which is allowed to cool off. At the end of two hours furnace No. 2 is thrown out of the circuit and work begun on furnace No. 3. By this time No. 1 is ready to be discharged. The lid is removed and water is used with a sprinkling pot to quench the fire still remaining. At the bottom of the furnace, on the floor of fine charcoal, is found an oblong metallic and crystalline mass of white metal. It is the copper charged with from fifteen to thirty-five per cent. of aluminum and a small quantity of silicon. It frequently averages twenty per cent. to twenty-two per cent. of aluminum and silicon. Covering this mass is also found a considerable quantity of fused carbide of aluminum. Analysis of this product has shown thirty to sixty per cent. of metallic aluminum present. On cooling, it forms very large and distinct crystals.

The very rich white bronze is collected together, put into an ordinary graphite crucible, and run into ingots weighing fifty or sixty pounds. These are carefully analyzed by the chemist, after which they are remelted and copper is added to them in the proper proportion to reduce them to the standard ten per cent. aluminum-bronze. To guard against mistakes being made in the analysis of the white and brittle ingots in the amount of copper added thereto, and in keeping the bronze free from impurity, every ingot of ten per cent. aluminum-bronze has its tensile strength tested, and it must show a tenacity of at least 90,000 pounds to the square inch.

As to the capacity of our large dynamo, and the economy of the process, a few figures may be interesting. In ordinary circumstances we expect to average a daily production of at least 300 pounds of ten per cent. aluminum-bronze for twenty hours' work with each machine of this size. In addition to this 300 pounds of bronze, containing in round numbers thirty pounds of aluminum, there is produced about sixty pounds of metallic aluminum in the bye-products, a large portion of which, with proper concentrating apparatus, will be cheaply reclaimed and rendered marketable. Ninety pounds of aluminum in twenty hours is a production of four and one-half pounds per hour. Four and one-half pounds per

hour produced by the energy of 120 horse-power equals the consumption of about 26·6 horse-power per hour to reduce one pound of aluminum. At times we have far exceeded this result. Indeed, two heats have been made wherein the energy consumed has been but twelve and one-half horse-power per hour per pound of metallic aluminum produced. Theoretically it should consume only about four and one-half horse-power per hour to effect the reduction, and in a new form of compound furnace to be built at our Lockport works, and in which 1,000 horse-power will be consumed, it is confidently expected that the output of bronze will not consume more than fifteen to twenty horse-power per hour for the reduction of one pound of aluminum.

Economy of the Process.—This may best be judged by the public in a general way from the fact that we are selling our ten per cent. aluminum-bronze as low in some instances as forty-five cents per pound net, and we are not selling it at a loss financially. This same bronze cannot be purchased elsewhere for less than $1.30 per pound. Our list price on ten per cent. bronze is sixty cents per pound.

The two and one-half per cent., five per cent. and seven and one-half per cent. bronzes are all proportionately less in cost. By the addition of zinc to the lower grades of aluminum-bronze an aluminum-brass is produced which is at once tough and malleable and of at least three times the tensile strength of ordinary brass. This brass has also vastly superior power to resist corrosion and oxidization. It can be made from the aluminum-bronze at a total cost of eighteen or twenty cents per pound.

Value of Electric Smelting.—"The Cowles Electric Smelting and Aluminum Company" claims that its process of electric smelting, within the next five or ten years, is destined to as completely revolutionize the brass and bronze trade of the world as the Bessemer converter has the iron and steel industry. This claim is based simply upon the ease and cheapness by which it can produce the alloys of aluminum and silicon, and the vast superiority of these alloys over any composition now in the market. It is further believed that cheap aluminum-bronze means a new era in warfare; that it insures a return to the age of bronze in the matter of heavy cannon, armor plates, gun carriages and small firearms. Why aluminum-bronze is the best metal for heavy guns is because sound, reliable and malleable castings can be made

of at least fifty tons tensile strength per square inch, an endurance that far exceeds that of any forged iron or steel when made into heavy guns, and a finished gun of this kind can probably be manufactured in one-quarter of the time and at far less the cost of one made of steel. Heavy pieces of steel ordnance now cost from seventy-five cents to $1 per pound, require a vast plant for their production and a very long time for completion. The same guns made from aluminum-bronze could be cast in an ordinary foundry of sufficient capacity and finished in a lathe, thus avoiding all forging, welding, shrinking on of rings, tempering, drilling and annealing now required in the manipulation of heavy steel and iron cannons. Armor plates for heavy fortifications and ships could be made completely from cast metal, no machine work being required to finish them ready to go into place.

For cartridges, we believe that sheet aluminum-bronze will prove to be unrivalled by any composition now known, for it is the only cheap metal not affected chemically by gunpowder, and that in turn does not deteriorate the gunpowder when stored for a period of years. It is so strong, and so much less in specific gravity than brass or copper, that the cartridge shell may be made of one-half the weight now required. Aluminum-bronze is likewise most admirably adapted, on account of its enormous tenacity and stiffness and resistance to all forms of corrosion, for torpedo boat cylinders and steam boilers, seamless tubes, stay bolts, and particularly rivets, where great strength is required and there is any tendency to shear off the heads, for it is as easy to obtain fifty tons tensile strength in an aluminum-bronze rivet as it is twenty-five tons in iron.

The Future of the Process is one of great promise, and will undoubtedly lead to the production of cheap and pure aluminum itself within a very brief period.* Indeed, "The Cowles Electric Smelting Company" asserts, on the back page of its pamphlet, that it expects to put the pure metal on the market within a year. When you are informed that we can charge iron, manganese, tin, copper, nickel, etc., with a very high percentage of metallic aluminum in this furnace, and that, also, without any base metal in the furnace, we can saturate the charcoal contained therein with metallic aluminum, most of which will be in a state of mechanical

* See Note at end.

mixture with the carbon; and further, that we have produced specimens of aluminum ninety-nine per cent. pure in at least three different methods by the electric furnace; and that notwithstanding all this we have not made much of an effort in this direction, the majority of you will agree that the great problem of producing pure and cheap aluminum is practically solved. How cheap this method will be you may judge from the fact that, at our Lockport works, which will have a capacity of only two or three tons per day, we expect to produce the aluminum in bronze with the little silicon contained in it at a cost not to exceed forty cents per pound, or with copper at twelve cents per pound, the bronze will really cost but about fifteen cents per pound.

In truth, "The Cowles Electric Smelting and Aluminum Company" is founded upon the faith that ere long we shall be marketing pure aluminum at a cost not exceeding fifty or sixty cents per pound. An appreciation of how cheap this would be, can be had from the fact that one pound of aluminum would go about as far as three and one-half of copper, it being that much more bulky, and in reality it would be about as cheap as copper at eighteen cents per pound, without counting its vast superiority over copper for many purposes on account of its greater lightness and resistance to corrosive influence.

Thanking you, gentlemen, for your attention, I would respectfully call your attention to a collection of ore, carbon, white bronze, furnace products, specimens of sheet and wire, and other manufactures of aluminum-bronze, that I have brought with me for your inspection.

[NOTE.—Since the above paper was filed with the Secretary of the Institute, it was found possible to prolong the length of the "heats" of the furnace to five hours, and increase the charges to over 100 pounds in weight, and during the same week a button of cast aluminum, five ounces in weight, was separated from the matrix of carbon, in which it was reduced by a process so simple and economical, that the production of pure aluminum from its oxide by the agency of heat and carbon only, is now demonstrated beyond all question.—E. H. C.]

DISCUSSION.

MR. THOMAS SHAW.—"What do you estimate to be the cost of operating with water-power, as compared with steam-power?"

Mr. Cowles.—"Water-power is certainly the cheaper, where it can be had at first cost."

Mr. A. E. Outerbridge, Jr.—"Have you any idea, approximately, of the temperature developed in your furnace?"

Mr. Cowles.—"We have no opinion on this point, further than that the temperature is probably as high, or higher, in spots, than that of the arc, because of the fact that the heat is prevented from being wasted or dissipated, owing to the heat-retaining character of the surrounding walls."

Mr. Outerbridge.—"Does the metal flow away after reduction?"

Mr. Cowles.—"No; the capillary action of the pulverized charcoal prevented this from taking place, just as fine flour or dust sustains drops of water and prevents them from flowing away."

Mr. Shaw.—"How often is it necessary to renew the linings of your furnaces?"

Mr. Cowles.—"About once a week."

Prof. W. H. Greene.—"Have you succeeded in reducing metallic calcium from its oxide?"

Mr. Cowles.—"Professor Mabery has reported that we have done so, and Professor T. Sterry Hunt, who spent some time with us in Cleveland observing the action of our furnace, witnessed the run or heat in which the reduction was made. We have also reduced metallic boron from boracic acid, and silicon from silicic acid."

Dr. Goldschmidt.—"I saw at the meeting of the American Association for the Advancement of Science, two forms of silicon, one consisting of black crystalline particles, and the other greenish in color. What is the difference between them?"

Mr. Cowles.—"The greenish material we believe to be partially reduced silicon, or a new sub-oxide of silicon, not hitherto observed. Our reasons for this are that it is always found at an intermediate position, between the completely reduced silicon at the top and the fused silica at the bottom."

Mr. Outerbridge.—"Do you observe any relation between the percentage of silicon in your alloys and their ductility?"

Mr. Cowles.—"We believe that the small percentage of silicon obtained in the alloys is a benefit to them, by increasing their tensile strength. This is effected by the metallic silicon absorbing

any oxygen taken up by the metal in the process of casting, and rising to the surface as silica, thus freeing the metal from such impurity. This is proven by the fact that on European aluminum-bronzes, thus far made, have exhibited as high a tensile strength as our bronzes, by as much as twenty per cent. The highest test of an aluminum-bronze casting other than ours, that we know of, is 94,000 pounds per square inch, while a casting of ours, which was tested some two weeks ago at the Washington Navy Yard, by Lieut. Hall, exhibited a tenacity of over 114,000 pounds per square inch, and we can, and frequently do, make to order, metal of 100,000 tensile strength in castings, while 90.000 pounds tensile strength is our ordinary standard for ten per cent. bronze; in other words, we let none go out of our works having less than 90,000 strength."

MR. ——— —"Why does not the molten metal short-circuit the furnace?"

MR. COWLES.—"One reason for that probably is, that as the metal becomes highly heated its conductivity is greatly diminished; another, possibly, is that the formation of an alloy, such as aluminum-bronze, may still further decrease its conductivity, since it is well known that alloys are often higher in resistance than their constituent metals; but above all, the great preventive would be the volatilization of the metal as soon as any considerable portion of the current started through it, which would cause a boiling of the mass and thus break up any contacts that should be made between the electrodes. At least, whatever may be the true reason, we find that we have had little or no trouble from this cause during the year that we have been in operation."

THE SECRETARY.—"A few comments, Mr. President, on the general bearings of this important subject may not be out of place here, for the benefit of those who may not be familiar with its technical features. The late Sir William Siemens, I believe, was the first to suggest the utilization of the intense heating effect of the voltaic arc for metallurgical purposes. He carried this suggestion into practical effect, also, by constructing what he termed an 'Electric Furnace,' and at the Southampton meeting of the British Association, in 1878, he described a series of experiments which he had made with this furnace in melting steel, nickel, platinum and other refractory metals, which demonstrated the enormous heating effects attainable by this means.

"It is worthy of note, however, that nowhere in this paper does it appear that he had conceived the idea of using his furnace to effect chemical operations such as the reduction of refractory ores. That this should have escaped the notice of an intellect so keen, and so thoroughly practical in its bent, is quite remarkable. It remained for the Cowles brothers to take this step in advance. They conceived the idea of a metallurgical furnace in which the reducing action of carbon should be greatly reinforced and exalted by the enormous heat of the electric arc. The results which they have succeeded in obtaining, Mr. Cowles has set forth in his most interesting paper, and are visible in the instructive array of specimens which he exhibits before you.

"In view of what has been accomplished so early in the history of this invention, it is risking nothing to predict that when its capabilities shall have been fully developed, it must prove of great advantage to the metallurgical arts. Already, it is almost as good as assured, that it has solved the difficult problem of producing aluminum cheaply, so that we may expect soon to see it taking the leading position in the arts for which its remarkable qualities appear to fit it so eminently, and from which its high cost, as compared with copper, tin and other useful metals, has hitherto debarred it. The extraordinary reducing power of the electric furnace justifies the expectation also, that, with its aid, the world may soon be enriched by the gift of many alloys of unknown and remarkable qualities.

"The happy conception of the Cowles brothers has armed the metallurgist with a vastly more powerful weapon than he has hitherto commanded, with which he will be able to achieve results heretofore unattainable. I am sure you all join me in offering them the hearty congratulations of this Institute."

At the close of the discussion, the meeting passed a unanimous vote of thanks to Mr. Cowles for his able and interesting address.

A PYTHOGOREAN PYRAMID.—G. Petrowitsh has communicated to the French Academy a trigonometric study of a pyramid, to which attention was called by M. L. Hugo, and which has for its base a right-angled triangle. The sides of the base being respectively in the ratios of the numbers 3, 4, 5, the faces of the pyramid satisfy the equation $3^3 + 4^3 + 5^3 = 6^3$, the number 6 being the area of the base.—*Comptes Rendus, Sept. 14, 1885.*

A NEW APPLICATION OF THE PRINCIPLE OF COMPOSITE PHOTOGRAPHY TO THE IDENTIFICATION OF HANDWRITING.

Francis Galton was the first to point out in fugitive memoirs, and notably in his epoch-making work, "The Human Faculty," that one could sift the common from the accidental features of a number of objects by exposing them to a sensitized plate in such a manner that the similar parts of the different objects should occupy as nearly as possible the same part of the plate, and that each object should be exposed for only a fraction of the length of time necessary to complete a picture on the film used. This fraction depended generally, if not always, on the number of objects and on the sensitiveness of the film. For example, if there were eighteen objects and the plate took thirty-six seconds to develop, each object would ordinarily be exposed for two seconds. It is easy to see that the result in the finished picture would be that those features which all the objects had in common would be re-enforced by each separate exposure, whereas those features which were accidental or variable, and which would be different for every individual, would be exposed for but two seconds and would be so indistinct as practically to fade away. Where the object was to catch a family likeness by exposing all the members male and female to the same portion of the plate, the result is a curious medley of faint whiskers, and moustache; of hair parted in the middle and at the side; of female gowns with buttons to the throat and of male shooting jackets thrown open. But out of all this faint halo of confusion and blur, there starts a characteristic face which is the family type. Very often, too, this type face resembles noticeably two different members of a family between whom no one can find a resemblance. It is this latter fact (which might have been expected) that induced me to look to the process for aid in resolving the difficult problem of identity of origin in handwriting. When a number of animals of the same race are thus treated, the method secures the fixing of the race or family characteristics, etc., as the case may be. When a number of pictures or coins bearing different representations of the same individual or scene are the objects, the result is to obtain either the average appearance of the same thing under different conditions (as for instance a man at different times of

life), or the average of the impression made by identically the same thing on different artists. In this case, the merit of the process is that it constructs its image out of all that many pairs of trained eyes have seen, without giving undue weight to any one pair. So far then, these efforts have been directed to re-finding a lost or concealed existence through multiple testimony, very much as the law tries to get at the truth by examining a number of witnesses.

The case of handwriting is, however, a different one. With a given mental image before one of what one desires to write; and with a given relation of will-power, nerve sensitiveness and muscular force, the same signature could be repeated a thousand times, provided that all these conditions were invariable, and no others were superadded. So far from this being the case, however, every one of the factors just named, which produce a signature depends on physical and mental—in other words, on extraneous influences, to a very large degree. A desire to make an up stroke, and the movement commenced to effect this, is met by an unexpected obstacle in the paper, a slight twinge in the shoulder, or a sudden noise, and the projected line would show (were we sufficiently cognizant of the detailed working of all the complicated parts of our mental machinery) just the order in which the different sentient and executive parts of us had been affected, and to what extent. But while these ever-recurring accidents result in preventing the signature from ever being made exactly as intended,* the fact that no two of them effect the same kind or amount of deviation leaves it in the power of the experimenter to extract from this process the "ideal" signature—a signature which probably never was seen as it appears, and yet which so combines all the visible results of a particular will acting on a particular arm to trace a known design with a pen or pencil on paper, that it may justly be called the *type* signature of that writer. What was said of the resemblance of every object of a group to the composite made of that group (provided the objects chosen have any claim to be so associated), while often differing widely from other members of the same group, is true of handwriting. It has been remarked that the composite signature is an ideal, and never was realized. This is because the lines along which the strongest

* The word "intended" is used to imply the effect of the will through the hand if not modified by these accidents, and not conscious intention.

reënforcement is made are those where locally varying deviations most frequently cross. To put it in another form, suppose the lines a, b, c and d to be in agreement as follows: At the point a', b does not cross, but c and d do. At b', c does not cross, but d and a do. At c', d does not cross, but a and b do. The line which, without very minute inspection, would represent to the eye part of the ideal signature, would be that traced through the points a', b', c', d', because those points having superposed lines of three out of the four signatures would be darker, while the variations at each of these points would be indistinct.

In examining with care a composite signature as just described, it at once arrests the attention that the variations are not equally distributed over the entire body of the letter, but that there are regions of each letter where variation of a particular kind is noticeable, and other regions where there is little or none. The more writings of an individual are compared the more forcibly does this fact appear, until finally one is tempted to conclude that after a handwriting is once formed, it cannot *naturally* exhibit deviations except within a defined variation and in certain limited areas adjacent to the separate letters. It is thus as great an assistance to the observer to study the variations as to study the ideal signature. Indeed, the variations are all important in the matter of identification, and if there were no variations the method would be inapplicable. A comparatively small number of signatures will give the maximum and minimum of variation in any given region of one of the letters forming it. Moreover, the kind of variation is easily observed where there are a number together, so that the most perfect adept at forgery could hardly hope to simulate the microscopically minute characteristics of variations which are simply the visible expression of a series of indefinitely complex relations of muscle and nerve.

In a case which was recently brought before the Orphans' Court in this city, this principle of composite photography was for the first time applied by me to the purpose of identifying handwriting, and from the experience thus far gained, it is thought that it will better accomplish the object than will the mere opinions of the most experienced experts.

PERSIFOR FRAZER.

Philadelphia, January 19, 1886.

THE LAW OF CONDENSATION AND EXPANSION OF STEAM IN SINGLE AND COMPOUNDED CYLINDERS.

BY WILLIAM DENNIS MARKS,
Whitney Professor of Dynamical Engineering, University of Pennsylvania.

In this JOURNAL for August, 1880, the writer published a paper, ("The Limitations of the Steam Engine,") showing that condensation being neglected, the economy of steam used per horse-power per hour varied as the logarithm of the boiler pressure of the steam divided by the back pressure.

This it is true was only an approximation of a rude nature, but it showed conclusively the limitation of economy of expansion due to *Marriotte's Law* under such conditions as would appear most favorable to expansion of steam without condensation.

It further showed the slow increase of economy due to the law of logarithms, and would seem to limit expansions to ten or twelve volumes without further condition than that of restraining the size of a cylinder within reasonable limits for any given power.

The writer then remarked "both Watt and Oliver Evans were partially right in their attempts to increase the economy of the steam engine. Watt was right in perfecting more and more the vacuum obtained, and Evans in increasing the steam pressure at the boiler.

"Neither of them were wholly astray, but were soon met and their progress stopped by the slow increase of economy beyond certain limits, and by the practical difficulties arising from surface condensation in the pursuit of a partially apprehended law.

"It is evident that we are limited as to the steam pressure, and that a great increase or a great decrease of the back pressure by reason of the more perfect vacuums will render the point of cut-off so early, the mean effective pressure so low, *and the condensation so great*, that the necessary increase in the volume of the cylinder will prevent that compactness and concentration of power so desirable in the steam engine, and although it has already been shown that high rotative speed aids in rendering the engine compact we are also limited in that direction."

At the time of that writing the writer was not aware of any exact experimental work which was of such a systematic character as to lead to the statement of the law of condensation of steam in a utilizable form.

As a fact, probably Watt and a long line of followers knew that great expansions meant greater proportional losses through condensation.

I take the following paragraphs regarding Watt's work from "Galloway's History of the Steam Engine," page 30 (edition of 1828).

"But in the year 1763–64, having occasion to repair a model of Newcomen's engine belonging to the Natural Philosophy Class of the University, his mind was again directed to the subject. At this period his knowledge was principally derived from Desaguliers, and partly from Belidor. He set about repairing the model *as a mere mechanician*, and when that was done and set to work, he was surprised that its boiler was not supplied with steam, though apparently quite large enough (the cylinder of the model being two inches in diameter and six inches stroke and the boiler about nine inches in diameter); by blowing the fire, it was made to take a few strokes, but required an enormous quantity of injection water, though it was very lightly loaded by the column of water in the pump. It soon occurred to him that this was caused by the little cylinder exposing a greater surface to condense the steam than the cylinders of larger engines did in proportion to their respective contents, and it was found that by shortening the column of water, the boiler could supply the cylinder with steam and the engine would work regularly with a moderate quantity of injection. It now appeared that the cylinders being of brass would conduct heat much better than the cast iron cylinders of larger engines (which were generally lined with a strong crust), and that considerable advantage could be gained by making the cylinders of some substance that would receive and give out heat the slowest. A small cylinder of six inches diameter and twelve inches stroke was constructed of wood previously soaked in linseed oil and baked to dryness. Some experiments were made with it, but it was found that cylinders of wood were not at all likely to prove durable, and that the steam which was condensed in filling it still exceeded the proportion of that which was required in engines of larger dimensions. It was also ascertained that unless the temperature of the cylinder

itself were reduced as low as that of the vacuum, it would produce vapor of a temperature sufficient to resist part of the pressure of the atmosphere.

"All attempts, therefore, to reduce, by a better exhaustion by throwing in a greater quantity of injection water, was a waste of steam, for the larger quantities of injection cooled the cylinder so much as to require quantities of steam to heat it again, out of proportion to the power gained by having made a more perfect vacuum."

Thus we see that Watt recognized the condensation due to the relative surface exposed, as also that due to the difference of temperature between exhaust and initial steam. With the rude machines then in use, it was out of the question for him to attempt to reduce the condensation by high rotative speeds.

In a lecture delivered at the Institute of Civil Engineers, May, 1883, Sir William Thomson used the following words: "In physical science, a first essential step in the direction of learning any subject is to find principles of numerical reckoning, and methods for practically measuring some quality connected with it. I often say when you can measure what you are speaking about, and express it in numbers, you know something about it, but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the stage of science whatever the matter may be."

It was with the feeling so well expressed by Professor Thomson, that the writer undertook to find out, as well as he could, whether the Newtonian law of cooling was applicable to the action of steam inside the steam cylinder. In this JOURNAL, March, 1884, the attempt was made to follow the passage of steam through single and compounded cylinders in the following words, and to verify Newton's law of cooling in the case of steam:

"The order of events would seem to be as follows: The engine having attained its regular speed and the cylinder an average heat, the entering steam, touching the interior of the cylinder, condenses instantaneously, and warms it up to the temperature of the steam. This warmth proceeds to a depth proportional to the depth already cooled by the exhaust. The steam then expands after

cut-off, falling in temperature and losing heat, (1.) by warming up the cooled cylinder walls, (2.) in doing work. However, the heated iron of that part of the cylinder exposed before cut-off gives up heat and vaporizes the condensed water of initial condensation in the attempt to equalize the temperatures throughout the cylinder, which is effected by a transfer of condensation following the motion of the piston head. At the end of the stroke, the temperature of the whole internal *surface*, and of the steam, is that of the terminal pressure, the steam having really expanded with fresh accessions of heat and of vapor from that part of the cylinder exposed to initial steam that is exposed before the cut-off occurs.

"Next in the order of events, the exhaust opens, and the whole interior of the cylinder is exposed to the temperature of the exhaust, the piston and cylinder head being exposed on an average twice as long as the cylinder walls.

"In every engine, these changes whatever they may be, establish an equilibrium among themselves, and the result is that a certain uniform quantity of heat is lost each stroke, provided the thermal value of the steam does not vary."

Again, regarding compounded cylinders, the writer said:

"We have carefully followed the action of the steam while passing through one cylinder. Let us follow it through the two cylinders. The steam entering the non-condensing cylinder suffers initial condensation, in some instances quite copious, but not so great as if the non-condensing cylinder had the temperature of the exhaust, T_e; however, the cut-off being later than would occur with the same ultimate expansion, E, in a single cylinder, the initial condensation will be found to be very considerable.

"The steam being cut off in the non-condensing cylinder, re-evaporation begins, the expansion line being held closely to an equilateral hyperbola.

"This re-evaporation is, however, far from being complete, and at the end of the stroke communication is opened to the condensing cylinder. At this instant a relatively enormous initial condensation occurs, because of the great surface of condensing piston and cylinder head presented at the temperature of exhaust, but this condensation is met at once by the equally as active re-evaporation which simultaneously occurs from the whole interior

of the non-condensing cylinder, the result being the transferring of the condensation from the surface of the non-condensing cylinder to the surface of the condensing cylinder until the temperatures are equalized.

"After the violence of this first transfer of condensation has abated, the re-evaporation from the interior of both cylinders occurs with sufficient alacrity to hold the expansion curve closely to an equilateral hyperbola.

"If but two cylinders are used, the condensing cylinder is now opened to exhaust and the re-evaporated and vaporous steam enter the condenser, carrying much more heat than would appear from a calculation of the thermal value of the vaporous steam present at the end of expansion.

"Thus we see that at the present day the compound engine owes its possible greater efficiency to the physical attributes of iron rather than to the properties of steam, and that with the use of non-conducting materials, the necessity of compounding cylinders will vanish."

With a clear comprehension in a qualitative way of the phenomena of the condensation of steam, it might be possible to deduce a quantitative law which would serve for practical use, and which in combination with Marriotte's law would form a new law, serving to solve the problem of the most economical number of expansions for any type of engine.

The extreme limitations to expansion are at once placed by its logarithmic increase of economy; a law deduced by the writer from a combination of the Warrington-Thompson law for the expenditure of steam per horse-power per hour, and Marriotte's law of expansion without regard to condensation.

This logarithmic law of economy of steam receives a curious and practical verification at the hands of the builders of compound engines, who, as the result of many experiments never recorded, have fixed upon a ratio of one to three for non-condensing and condensing cylinders as the most economical for practical purposes.

In this Journal for January and February, 1884, I say:

"It has been shown that the ratio of volume of the cylinders of a compound engine is a function of the ultimate expansion of the steam under the conditions that the power of the cylinders is equalized, and that no drop be permitted in the steam pressure during its course through the engine.

TABLE OF RATIOS OF CYLINDERS AND POINTS OF CUT-OFF IN NON-CONDENSING CYLINDER AND FOR ULTIMATE EXPANSIONS OF STEAM.

$$\text{Criterion } \frac{2\ R \log.\ R}{R - 1} = \log.\ 2{\cdot}7183\ E$$

$$e = \frac{R}{E}.$$

Ratio of Cylinder Volumes.	Ultimate expansion of Steam.	Point of Cut-off in Non-Condensing Cylinder.	
R	E	e	
1¼	3·426	0·37	REMARKS.
1½	4·190	0·35	These computations are made for general guidance only, nearly all the assumptions made being impossible of exact realization.
1¾	5·015	0·34	It is assumed that a perfect gas is used expanding isothermally, that there is no back pressure on the condensing cylinder piston, and that there are no clearances or receiver, and further that there is no cut-off at all for the condensing cylinder, that only being demanded to provide for receivers and clearances in actual practice, and that the cranks are together, or 180° apart.
2	5·886	0·34	
2¼	6·813	0·33	
2½	7·801	0·32	
2¾	8·840	0·31	
3	9·933	0·30	
3¼	10·961	0·30	
3½	12·277	0·28	
3¾	13·580	0·28	
4	14·832	0·27	

"It is useless to carry this table farther. Enough has been done to show the error of exaggeration of ratio, into which designers have fallen, when it is necessary to equalize the power of cylinders and to avoid an intermediate drop for the sake of economy.

"Indeed, in all engines it will be found that economy of steam as well as smoothness of action, demand that no sudden changes of pressure shall be permitted, and therefore it will be found advantageous in single cylinder engines where clearance cannot be indefinitely reduced to use enough compression to bring the back pressure up to the initial pressure, and so as not to permit an *explosion* in the cylinder at the beginning of each stroke.

"Whenever, as is the case with condensing engines or small non-condensing engines, it is not practically possible to make the number of expansions equal to the boiler pressure divided by the back pressure, we still have the same impassable barrier to exceeding

ten or twelve expansions set by Marriotte's law regardless of condensation.

"It is not possible to avoid initial condensation, to construct an engine without clearance, or to obtain a perfect vacuum; but if, for the purpose of obtaining an extreme limit, we neglect these, the equation for weight of water per horse-power per hour (JOURNAL F. I., August, 1880,) becomes

$$W = \text{constant} \times \frac{1}{1 + \text{nat. log.} \frac{1}{e}}$$

"If in this we substitute successive values of e, we obtain the successive percentages of water used per horse-power per hour.

$$\text{For } e = 1 \text{ we have } \frac{1}{1 + \text{nat. log.} \frac{1}{e}} = 1{\cdot}00$$

$$\text{For } e = \tfrac{1}{4} \text{ we have } \frac{1}{1 + \text{nat. log.} \frac{1}{e}} = 0{\cdot}42$$

$$\text{For } e = \tfrac{1}{8} \text{ we have } \frac{1}{1 + \text{nat. log.} \frac{1}{e}} = 0{\cdot}32$$

$$\text{For } e = \tfrac{1}{9} \text{ we have } \frac{1}{1 + \text{nat. log.} \frac{1}{e}} = 0{\cdot}31$$

"The gain by increasing the expansion from eight to nine times is but a theoretical one per cent. at the outside, and possibly there is an actual loss in the case of small cylinders or slow piston speed." —JOUR. FRANKLIN INST., Dec., 1883.

It is necessary thus to set bounds to the extremes between which it is worth our while to consider the effect of initial condensation in the steam cylinder.

We see that in the case of large engines or compounded cylinders there may be a gain in exceeding ten expansions, but it is necessarily a very small one if it exist at all, and may not be worth having, in the long run, even in compound engines.

There is another point which the reader should bear in mind: the curve of expansion of steam, in the best engines made, coin-

cides, with as great accuracy as could be wished for, with the equilateral hyperbola, and it is nonsense to discuss the curve of adiabatic expansion for engines until we have an adiabatic engine produced. Further, as long as we know the equilateral hyperbola to be an average of the curves produced by good indicators on good engines, the condensation of the steam during expansion, or its re-evaporation—in fact, its behavior during expansion, is of minor importance.

The first step in the quantitative investigation of the problem of the initial condensation of steam is the establishment of a standard, and the writer chose to make it: *The weight of steam condensed by a plate of cast iron one foot square when raised one degree Fahrenheit in one minute.*

Of course, it would be more accurate to say, the heat units absorbed, in the place of the weight of steam condensed, but that was at that time quite accurate enough for his purposes, which were and are purely practical, in the sense of desiring to take cognizance of the real facts in proportion to their importance only, and of wishing to avoid an attempt to reach greater accuracy in results than his premises would warrant.

The writer was exceptionally fortunate in basing his first investigation upon the thorough and skilful work of Mr. John W. Hill, upon so perfect an engine as the Harris-Corliss, in the competitive tests at Cincinnati, 1880.

Mr. Hill's conscientiousness led him to frankly say that he could not indorse his calorimetric work, and the careful use of two calorimeters in each case, in the boiler tests of the Electrical Exhibition of 1884, at Philadelphia, proved the unreliability of calorimetric work, and of the present forms of calorimeters.

On the other hand, in making Mr. Hill's work our basis, we are sure of an engine whose piston was tight working under the most favorable conditions of good practice, and, therefore, of obtaining a value of the constant of condensation not grossly in error.

A careful copying of Mr. Hill's methods of recording his work would have added very much to the value of the more recent experiments of Messrs. Gately and Kletzsch, which, nevertheless, are of great value, as throwing light upon some unexplored fields.

The clearance should have been determined. Diagrams should

have been published in conjunction with the record, and the amount of compression should have been carefully noted, as it doubtless has an important effect upon the condensation of the initial steam.

The acknowledged errors of their work gives honorable proof of their sincerity and scientific spirit. Indeed, a long and searching examination of quite a number of reputed scientific experiments upon the steam engine, leads us to believe this characteristic much rarer than is generally supposed, if we have not misunderstood the internal evidence of the records.

In this JOURNAL for March, 1884, "Initial Condensation of Steam Cylinders," we stated the following formula for the ratio of the actual steam from the boiler to the steam indicated at the point of cut-off:

$$r = 1 + \frac{S\,[T_b - T_e]}{62\tfrac{1}{2}\,N}\;C\left[\frac{4}{d} + \frac{2}{e\,s}\right] \qquad (8)$$

in which r = ratio of actual to indicated steam at cut-off.
S = specific volume of steam at cut-off pressure.
T_b = temperature of steam at cut-off. (Fahr.)
T_e = temperature of steam during exhaust. (Fahr.)
N = number of strokes per minute.
d = the diameter of steam cylinder in feet.
s = the stroke of steam cylinder in feet.
e = the fraction of the stroke at which steam is cut-off.
C = the condensation in pounds per minute of one square foot raised 1° Fahr.

This formula assumes that the interior of the cylinder already let down in temperature by a low terminal pressure loses heat to a depth proportional to the time of exhaust $\frac{1}{N}$ minutes, and four expansions approximately.

As already stated the cylinder and piston head have on an average twice as long an exposure to exhaust as the circular barrel of the cylinder.

It is to this value of C, the constant of condensation, that we must look to solve the vexed and much disputed question of the utility of steam jackets versus clothing of non-conducting materials. The following table, with the exception of Mr. Hill's experiments, has been computed for me by Assistant Engineer G. H. Bull, U. S. N.

:s,
ut
as
e-
ıe
re
:r-
ɔn
he

ɔh

he
of
ıo-

he

ɔh

-1

TABLE OF RESULTS OF EXPERIMENT AND CALCULATION OF CONDENSATION AND EXPANSION OF STEAM.

Experiments of J. W. Hill upon Harris-Corliss Engine, Cincinnati, 1880.

Number.	Stroke of Cylinder in Feet. s	Diameter of Cylinder in Feet. d	Fraction of Stroke Cut-off. Reciprocal of True Number of Expansions. e	Number of Strokes per Minute. N	Absolute Steam Pressure at Cut-off. Pounds. P_b	Absolute Steam Pressure during Exhaust. B	Temperature of Steam at Cut-off. Fahrenheit. T_b	Temperature of Steam during Exhaust. Fahrenheit. T_e	Specific Volume of Steam at Cut off. S	Ratio of Actual to Indicated Steam at Cut-off. r	Condensation Constant. C	Averages.	
(1)	4·08	1·5	·1355	151·66	101·67		328·8	145·4	264·	1·657	·01868		Condensing. 10 hours' test.
(2)	4·08	1·5	·1491	151·62	100·61		328	212·6	266·5	1·559	·02642		Non-condensing. 10 hours' test.
					Experiments of Gately and Kletzsch. Harris-Corliss Engine. Sandy Hook, 1884.								
					CASE I.—Variable Cut-off Only. Condensing.								
(3)	3·5	1·5	**·589**	136·52	61·54	4·22	294·2	155·2	430·	1·294	·011554		
(4)	3·5	1·5	**·443**	135·9	68·34	3·91	301·14	152·15	390·13	1·371	·013717		
(5)	3·5	1·5	**·330**	134·64	62·10	4·48	204·80	157·56	426·35	1·512	·016704		
(6)	3·5	1·5	**·131**	137·9	49·11	3·65	279·84	149·44	530·9	2·003	·017762		
											·059737	·014934	
					CASE II.—Variable Steam Pressures Only. Condensing.								
(7)	3·5	1·5	·208	138·03	**78·80**	3·24	311·02	144·58	342·2	1·544	·015225		
(8)	3·5	1·5	·206	141·44	**66·89**	3·83	299·69	151·88	398·1	1·917	im-possible		·025331 C.
(9)	3·5	1·5	·244	143·46	**53·21**	3·24	284·95	144·58	492·1	1·583	·013564		
(10)	3·5	1·5	·210	137·82	**39·83**	3·61	266·74	149·02	642·9	1·707	·014952		
(11)	3·5	1·5	·242	135·85	**26·74**	3·46	244·26	147·21	936·6	1·700	·013013		
		Average	·226								·056754	·014188	
					CASE III.—Variable Steam Pressures Only. Non-condensing.								
(12)	3·5	1·5	·412	135·96	**65·36**	14·70	298·16	212·	407·5	1·122	·007267		
(13)	3·5	1·5	·420	137·14	**50·42**	14·82	281·30	212·4	504·5	1·307	·018810		
(14)	3·5	1·5	·401	135·02	**40·52**	14·88	267·87	212·6	620·8	1·190	·011390		
(15)	3·5	1·5	·466	133·04	**28·40**	14·84	247·56	212·49	886·6	1·376	im-possible		C = ·032721.
		Average	·425								·037467	·012489	
					CASE IV.—Variable Number of Strokes. Condensing.								
(16)	3·5	1·5	·938	**125·95**	27·30	3·15	245·56	146·31	916·2	1·322	·008515		
(17)	3·5	1·5	·961	**100·6**	28·35	3·86	247·46	151·57	886·8	1·403	·009150		
(18)	3·5	1·5	·981	**67·48**	28·53	4·96	247·81	161·94	881·6	1·504	·008640		
		Average	·960								·026305	·008768	

From the more reliable figures of the two calorimetric results, given by Hill, it was found that the steam was super-heated about 200° Fahr., and in the paper of March, 1884, the assumption was made that the temperature of the steam was 532°, as also of the interior of the cylinder. In this table, the assumption is made that the temperature at cut-off is 328° that of saturated steam at the pressure of cut-off, and the weight of steam *C* is further corrected for superheating. The correction shown, formula (9) *et seq.*, has not been made and would give the correct value of *C*, much less, than the apparent one of the table. (*See Table.*)

The first method gives the more concordant results with a much less apparent value, in the case of Hill's experiments.

If we take account of the variable time of exposure of the cylindrical walls of the cylinder, as also of the variable value of the area of the cylindrical elements, we have for the time of exposure to exhaust, multiplied by the area,

For the piston head and the cylinder head.

$$\frac{\pi\, d^2}{2\, N}$$

For the variable area for each increment of the angle x, the crank being assumed to have a uniform rotary motion,

$$(\pi\, d)\, d\, s = + (\pi\, d) \frac{s}{2} \sin x\, d\, x$$

For the variable time $\frac{x}{180\, N}$ of exposure to exhaust of each element $(\pi\, d)\, d\, s$. For their product

$$\frac{\pi\, d\, s}{2\, N}\, \frac{x}{180} \sin x\, d\, x$$

For the product of interior of cylinder, between limits,

$$\frac{\pi\, d}{2\, N} \left[d + \frac{s}{180} \int_{x = \cos^{-1}(2\, e - 1)}^{x = 180^\circ} x \sin x\, d\, x \right]$$

but, $\int x \sin x\, d\, x = \sin x - x \cos x$

for $x = 180^\circ$ we have π

for $x = \cos^{-1}(2\, e - 1)$, we have $\sqrt{1 - (2\, e - 1)^2}\, (2\, e - 1) \cos^{-1} (2\, e - 1)$

Therefore we have, as a final quantity for any cut-off e,

$$\frac{\pi d}{2 N}\left[d + \frac{s}{\pi}\{\pi - \sqrt{1-(2e-1)^2} + (2e-1)\cos^{-1}(2e-1)\}\right] \quad (9)$$

This latter expression should be multiplied by $(T_b - T_e)$ and placed within the square parenthesis of Formula 7, JOURNAL OF THE FRANKLIN INSTITUTE, March, 1884, should more exact results be demanded than are given by Formula 8, of same paper.

The last expression deduced will make considerable difference in the apparent condensation C per degree Fahrenheit of a square foot of iron in one minute, when we consider very early or late cut-offs, but as this is rarely the case where economy is desired, it is not of very great importance except in special cases.

Taking a value of $e = \frac{1}{4}$, we have from the previous expression

$$\frac{\pi d}{2 N}(d + 0{\cdot}4\, s) \text{ very nearly.}$$

If we substitute the same value $e = \frac{1}{4}$ in Formula 7 we have

$$\frac{\pi d}{2 N}(d + 0{\cdot}5\, s) = \frac{\pi d}{2 N}(1{\cdot}5 + 1{\cdot}75) = (\ )\ 3{\cdot}25 \quad (10)$$

We see that it is hardly worth while to put ourselves to the trouble of the more complicated and correct formula as we rarely cut off later than $\frac{1}{4}$ in good engines of any size, and do not exceed that save in large engines, where careful work must always be done.

The average cut-off of Case III, Gately and Kletzsch experiments is $e = {\cdot}425$ and the condensation $C = {\cdot}012489$.

Substituting this value of e in expression (9), we have

$$\frac{\pi d}{2 N}(d - {\cdot}656\, s) = \frac{\pi d}{2 N}(1{\cdot}5 + 2{\cdot}296) = (\ )\ 3{\cdot}80 \quad (11)$$

Dividing the condensation ·0125 by 3·25, and multiplying by 3·80, we have ·0146 for the corrected value.

In Case IV, of the same experiments, $e = {\cdot}96$ and $C = {\cdot}0088$, we have from expression 9,

$$\frac{\pi d}{2 N}(d + {\cdot}991\, s) = \frac{\pi d}{2 N}(1{\cdot}5 + 3{\cdot}468) = (\ )\ 4{\cdot}968$$

Dividing $C = {\cdot}0088$ by 3·25, and multiplying by 4·968, we obtain ·0145.

Showing with the greatest certainty which now can be obtained that the condensation is directly proportional to the area exposed and its time of exposure to exhaust steam.

Since these concordant experiments were made with and without condenser at varying speeds, ranging from sixty-seven to 143 strokes per minute, with pressure varying from twenty-seven to seventy-nine pounds per square inch at cut-off, and with cut-offs varying from 0·21 to 0·98 of the stroke, it would seem permissible to assume the law of initial condensation of steam to have been correctly stated in the paper of March, 1884, JOURNAL FRANKLIN INSTITUTE

At the time of that writing, the author could find but one record, of an engine proved tight, which *seemed* accurate, and, feeling the natural hesitancy of one on wholly new ground, made the following remarks:

"The writer presents himself to his readers, not in the attitude of one having authority, but merely as a patient student of the real facts of the action of steam inside of the steam cylinder.

"So far as he knows, no writer, from the time of Carnot to this present date, has essayed to include all the data which must affect the condensation of steam in one general formula applicable to all cases.

"The factors which must enter into such a formula will be seen to be too numerous to admit of the graphical treatment which, following the high authority of Rankine, quite a number of his followers have essayed, with varying degrees of approximation to correctness of result, and apparently quite oblivious to the fact that they are reasoning in a circle from empirical statement of experimental results, and that they are shut out completely from the hope of logically searching for the best attainable conditions in the use of steam.

"Should it prove that this discussion of initial condensation is a scaffolding for the walls and roof of a structure which will house all the warring experimental proofs and mathematical discussions as to economy of steam, and that the hitherto unknown law of condensation of steam inside of the cylinder of a steam engine, has been formulated with practical accuracy; the writer will regard himself as most fortunate, in having been able to complete the actual theory of the steam engine at work.

"To the skilled mathematician and physicist, the use of thermal units in the place of weight of steam will give more exact results, *when we have sufficiently accurate premises to justify a reasonable belief that it is worth our while to use thermal units throughout.* At this point, too, we must not forget the condensation due to expansion, which has formed so favorite a theme for writers on thermodynamics.

"The use of the Metric system will also lighten the labors of one having a large amount of calculation to perform.

"In this departure from older paths, the writer cannot but feel that he is far from sure of his ground at all points, nor does he lay claim to infallibility, but presents his facts, computations and ideas for your your consideration and verification."

The writer now feels that he can justly lay claim to having established, by original methods of investigation, and with as great accuracy as can be reached in ordinary practice, the following laws of the action of steam in a steam cylinder.

The logarithmic law of economy of steam using, regardless of condensation, giving the extreme limitations of the expansion of steam—

(1.) When the number of expansions is equal to the boiler pressure, divided by the back pressure on piston.—JOURNAL FRANKLIN INSTITUTE, August, 1880.

(2.) When any number of expansions are used at will, with a given pressure.—JOUR. F. I., Dec., 1883, and Aug., 1880.

The law showing the ratio of the cylinders of a compound engine to be a function of the ultimate number of expansions under the condition of the most economical use of steam.—JOUR. F. I., Jan. and Feb. 1884.

The law of the initial condensation of steam in a steam cylinder.

The general laws of the economic expansion of steam under any conditions existing in steam cylinders, simple or compounded.

The establishment of a standard of condensation C, which will serve by proper experiment to determine the utility of steam jackets.—JOUR. F. I., March, 1884.

The inference from the general law of initial condensation that compression to boiler pressure reduces this condensation to a constant and a minimum under the assumption of four expansions. (approx.)—JOUR. F. I., June, 1884.

In addition to the experiments of Watt, we have a large number by D. K. Clark, G. A. Hirn and Chief Engineers Isherwood, Loring and Emery, all proving, under certain conditions, the overwhelming influence of initial condensation in the steam cylinder, but the writer is not aware that any of them has established a rational and general law, applicable in all cases where the piston and valves are proven tight

Philadelphia, January 18, 1886.

RAPID TRANSIT AND ELEVATED RAILROADS, WITH A DESCRIPTION OF THE MEIGS ELEVATED RAILWAY SYSTEM.*

BY FRANCIS E. GALLOUPE, M. E., BOSTON, MASS.

[*Continued from Volume CXXI, page 76.*]

Objects.—The Meigs elevated railway system is designed to meet the modern demand, and all the ordinary requirements of a railroad for the safe, quick and convenient transportation of passengers in cities, or to and from the suburbs of cities to such central points as passengers desire to go; while on longer lines, connecting cities and towns, to carry both passengers and freight, not only more economically and safely, but more speedily than has heretofore been done.

The New York structure is essentially an ordinary railroad, elevated, and is open to the criticisms of liability to derailment and consequent want of safety; a too great height of the position of the centre of gravity, and want of stability, by reason of the large leverage upon the posts when sustaining wind pressure upon the sides of the cars; and the well-known obstruction to light and air produced by the size of the structure in the street.

The fundamental principle of construction in the Meigs system is to *concentrate the strains due to the load upon the track directly upon the central line of the way*, avoiding all disadvantageous leverage. It is, in effect, to turn the ordinary track up edgewise, or vertically, with one rail lying directly over the other, instead of

* A paper read at the Boston meeting, 1884, of the Amer. Soc. Mechanical Engineers, and reprinted from advance sheets of the *Transactions*.

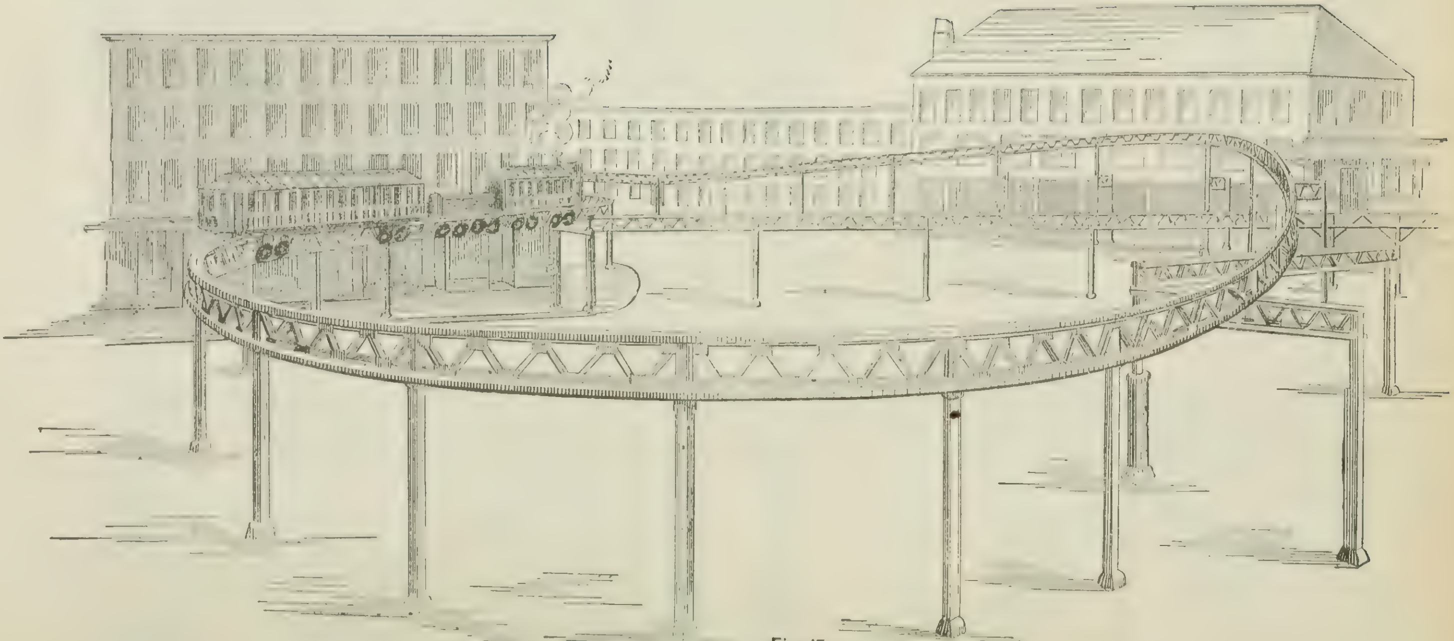


Fig. 17
GENERAL VIEW
Meigs's Elevated Railway.

side by side in a horizontal plane, as in all other railroads. Or, it is as though the Y of the posts in the New York system, as well as all the cross-ties, nine feet in length, were abandoned, and the double girder beneath the track condensed into a single central truss, removing four-fifths of the material causing obstruction to light and sight from the street.

Its general appearance is shown by *Fig. 17*.

In the execution of the design based upon these peculiar conditions, the roadway consists of a single lattice iron girder or truss, four feet in depth, and resting upon iron posts or columns placed 44·4 feet apart.

Distinguishing Features.—Its peculiar features and differences from the ordinary railroad exist in—

(1.) The Way;
(2.) The Switch;
(3.) The Trucks;
(4.) The Passenger Cars;
(5.) The Engine;
(6.) The Draw Bar; and
(7.) The Brakes;

as in the following description:

I. THE POSTS AND FOUNDATIONS.

The posts may be of wood, rough, hewed, or sawn square, for the wooden track system; or of iron when the iron way is used. In the latter case they will be of rectangular form, about 11 inches by 10 inches in section, and 24 feet in length. They are composed usually of two medium ten-inch channel bars, *f f*, *Fig. 22*, and two plates, *e e*, all about one-half inch in thickness, riveted upon and along the flanges of the channel bars and the edges of the plates. They thus form a hollow box-like structure, which may be varied in cross-section or thickness in special places, or may have the solid plates replaced by diagonal bars riveted in lattice form upon the channel bars. The weight of each post, having a sectional area of 23·8 square inches, is 1,919 pounds, the crushing load 235 tons, and safe load thirty-nine tons, while the greatest load that will be imposed on a post in any position of a passing train will not exceed thirty-five tons.

The foundations, as shown in *Fig. 18*, (this and all subsequent figures being in scale one-thirty-second of full size, or three-eighths

inch to the foot,) being a vertical section, and *Fig. 23* a horizontal section of one form, consists of a plate *c*, upon which the post rests, of somewhat larger area than the post, as shown in *Figs. 18* and *20*, or of a similar plate *c'*, as shown in *Fig. 19*, which has an upwardly presenting boss entering into its interior, set in and on a concrete foundation about 3 feet in diameter and 6 feet in depth. The

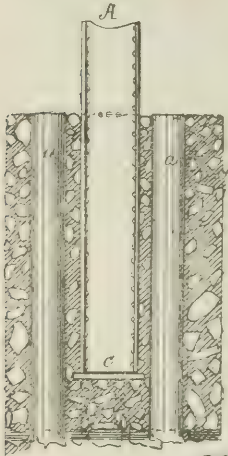


Fig. 18

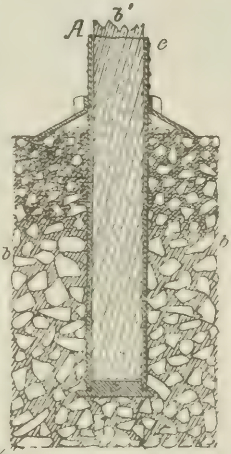


Fig 19

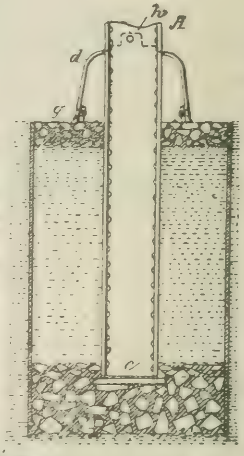


Fig. 20

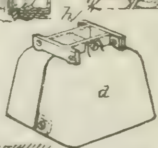


Fig 21

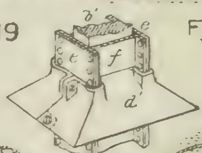


Fig 22

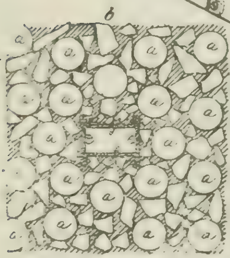


Fig. 23

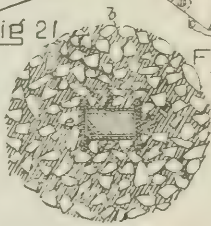


Fig. 24

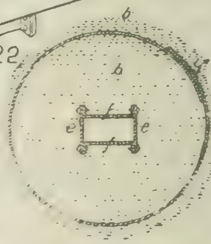


Fig 25

lower part of the posts may remain hollow, or they may be filled with concrete, *b'*, or with sand or other non-compressible filling, as shown in *Fig. 19*.

If the foundation is upon soft earth, the earth is packed, as shown in *Figs. 18* and *23*, by driving piles, marked *a*, all around the place where the post is to be set, and filling between, and over them, if necessary, with the concrete.

Where this is not necessary, another plan, shown in *Figs. 19* and *24*, is more usually followed, in which the post hole is simply filled with concrete and broken stone below.

Where the ground foundation is good, but the surface soil is mobile, as in the Mississippi valley and elsewhere, in which case side thrusts are not well resisted, still another method, shown in *Figs. 20* and *25*, may be employed, consisting of a stout resistant boxing or lining to the post hole, of iron or wood, as shown at *g*, and filled with concrete or sand inclosed between concrete ends, thus forming a strong side support to the post, practically increasing its section below the ground many times. At the surface of the ground the posts may, if advisable, be additionally braced or guarded from abrasion and injury by passing vehicles by means of caps or collars, *d* or *d′*, shown in *Figs. 21* and *22*. These are either of cast or wrought iron, made in two parts, and bolted together and to the post by means of ears or bolts passing through the post.

These posts, so set, at a distance of 44·4 feet apart, will be amply sufficient in strength to carry safely a girder capable of supporting substantially such trains as are now in general use, at a height of at least fourteen feet from the ground to the bottom of the girder.

II. THE WAY.

The way upon which the train runs, *Figs. 26* and *28*, consists, as before stated, of a single iron girder or truss for each span, four feet in depth, placed centrally over the line of posts, and comprises an upper track-beam, a lower track-beam, upon the sides of each of which are carried the rails, and between these track-beams the bracing or trussing. At the proper height for resting the lower track-beam the bracket angle-irons, *i*, are riveted upon each post, and on these irons the lower portion of the girder rests. The upper track-beam rests upon the extreme top of the posts, and through the diagonal braces supports the trucks and cars, whose weight is carried upon the lower track-beam.

The lower track-beam of the girder, *C*, is a box-beam, composed of two channel bars, *l l*, *Fig. 26*, to which are riveted flat plates, *k k*, which in turn are securely riveted to the post sides by angle-irons. In the exterior recesses formed by the channel bars are imbedded wooden beams, *m m*, one on either side of the line

of posts, which may be single sticks or composite beams made up of several pieces, and which act as rail stringers. Across the girdər at intervals of about two feet are riveted **T** or double angle-irons, as shown at *n*, *Fig. 28*, in order to bring the entire strength of the iron into action.

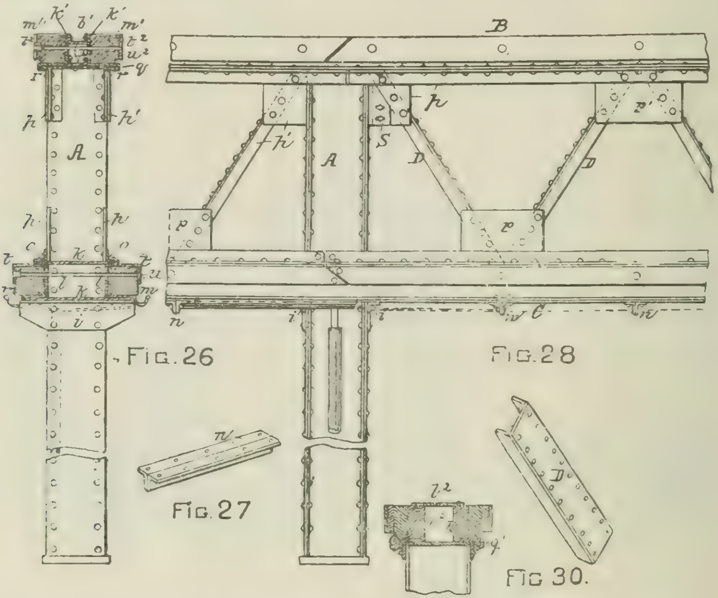


FIG. 26

FIG. 28

FIG. 27

FIG. 29

FIG 30.

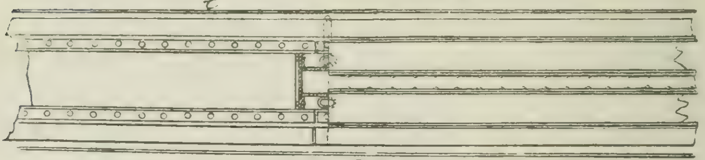


FIG 31.

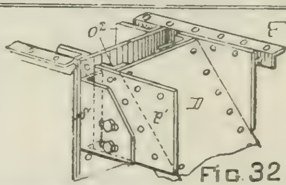


FIG. 32

In the angle formed by the upper plate, *k*, of the box-beam, *C*, with the channel bars, *l*, on its outside, the angle-irons, *O*, are also riveted. These may be made much deeper than shown, so as considerably to stiffen the girder and serve as attachments for the braces, *D*; or, as shown, attachment plates, *p*, are inserted at the

proper intervals and riveted to the angle-irons, *O*, and diagonal braces, *D*, composed, as shown in *Fig. 30*, of two angle-irons and a plate, or of channel bars, or I beams, attached by similar plates to the upper track-beam.

The upper track-beam, *B*, of the girder, is also a box-beam, composed of two channel bars, $l' \, l'$, and two exterior angle-irons, $k' \, k'$, reinforced by angle-irons, *r r*, all well riveted together and carrying in the recess formed by the exterior angle-irons the stringer beams, $m' \, m'$, of solid or compound sticks of timber, for supporting the rails, as described.

An expansion joint, *Fig. 32*, is formed at the end of these upper track-beams, by means of a bracket, *S*, firmly riveted to the post, to which the brace portion, *D*, and the attachment plates, p', are fastened by bolts passing through slots of sufficient length to allow for the ordinary expansion or movement of each section of the way, due to changes of temperature.

The lower surface of the upper box-beam rests upon a terminal plate at the top of the post, which thus takes its weight, so that these brackets in the slip-joint serve only as guides. The upper beam may also be made up as shown in *Fig. 29*, in which g' is the lower plate connecting the two lateral channel bars of unequal flanges, $k^2 \, k^2$, and l^2 a top plate to form the box-beam. The purpose of using wood for the track stringers is not only to form a continuous support for the rails and a convenient substance for the attachment of the rail fastenings, but to assist in the preservation of the alignment of the way due to its freedom from expansion by heat, and also to aid the iron work in resisting longitudinal stresses upon the girder, as in braking a train. It also supplies required elasticity for rails and girder, saving the iron from unnecessary wear from knocking and pounding, in several important respects.

The rails of this structure are four in number; the two bearing rails, which carry the load of the car, being angle-irons placed upon the outer upper edge of the stringers, *m*, upon the lower track-beam. They are marked *t* in the figures, and are fastened to each other, to the stringer-beams, and to the lower track-beam of the girder by through-bolts, *u*, as shown. The upper track-beam also carries two vertically placed rails for the balancing or friction wheels, lettered $t^2 \, t^2$, and are similarly held to the stringers, which project over the line of posts and braces and have a small recess

beneath them under which flanges upon the horizontal wheels run to securely lock the truck upon the track.

The horizontal distance from outside to outside between the lower rails which is found to be sufficient for transverse stiffness is twenty-two and a-half inches, which thus constitutes the gauge of the road and the total width of the way with its rails in the street; the corresponding gauge of the upper rails being seventeen and one-half inches.

It is anticipated that the form of rail section in common use will be eventually adopted in permanent constructions, in which case the lower wooden stringers would be chamfered off at their upper outward corners to take the rails, whose axes would incline at an angle of about 45° with the vertical. The length of the posts, twenty-four feet being usually sufficient, occupying four feet for the truss and six below the surface of the ground, giving fourteen feet clear way beneath the truss, will be varied to follow the grades and contour of the ground; and at freight houses the girder may be sunk below the surface two feet, to facilitate unloading upon low platforms or into teams, or remain at grade, the platforms and road being raised the same amount.

The present cost of building the permanent way is about as follows:

				Per Mile.
Iron	Way,	with	high posts, ...	$70,000 to $75,000
"	"	"	low posts, ...	50,000 to 55,000
Wooden	"	"	angle-iron rails, ...	20,000 to 25,000
"	"	"	round posts and sawed wooden rails,*	6,500
"	"	"	hewed track-stringers and hard wood rails,*	4,500

III. THE SWITCH.

The switch, *Figs. 37* and *38*, consists in simply swinging a single section of the way upon a peculiarly constructed and very strong hinge attached to one of the posts.

In *Figs. 34* and *37*, *F*, and the continuance beyond the other post, d^9, are portions of the main line; h^5 h^5, the section composing the switch; h^4, its hinge, the whole being shown in plan in *Fig. 37*.

The movement of the switch must be sufficient to enable the cars and trucks on one track to clear the end of the rail on the

* Estimate of H. Haupt, C. E. In a timber country and with the cheapest possible wooden construction throughout.

other track, or some four or five feet. When operated, the free end is swung over upon the supporting carriage provided with rollers travelling upon the supporting rail v, being operated by suitable chains and rag wheels by means of a winch or hand-wheel,

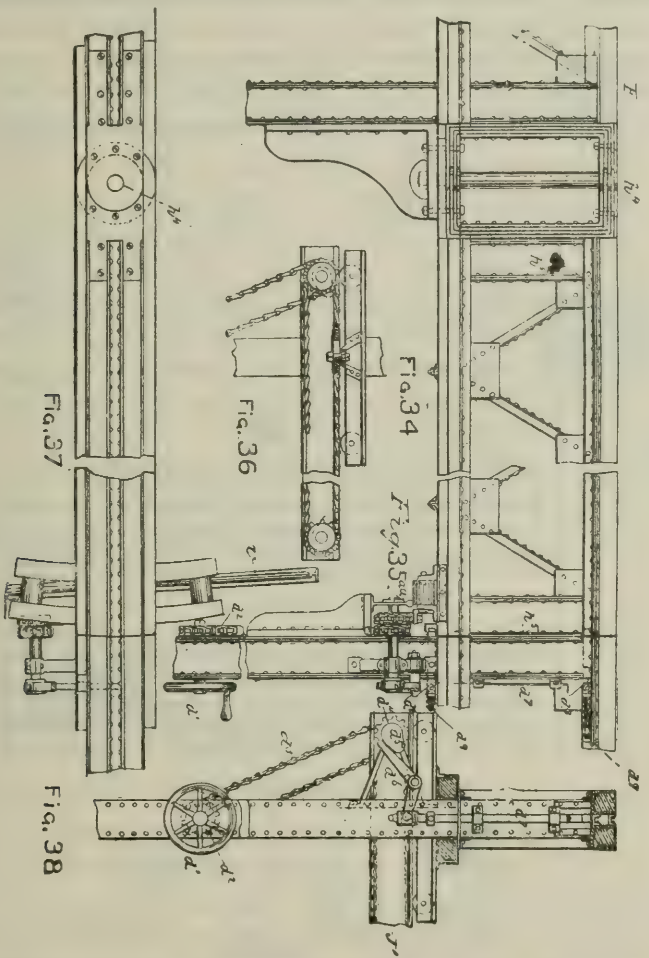


Fig. 34. Fig. 35. Fig. 36. Fig. 37. Fig. 38.

d^1, *Fig. 38*, and locked in position by a locking device shown in *Figs. 35* and *38*. *Fig. 36* shows the connection of the rag-chain with the free end of the switch and its carriage.

The hinge is strongly bracketed out from the post at the end of the main way, *F*, as shown in *Fig. 34*, and consists of a series

of curved iron plates arranged concentrically around the pivot-pin or pintle, h^4. One-half of these plates are attached to the swinging section and one-half to the post, the series on each being composed of alternate layers of concave and convex ended plates which shut into each other so as to retain the strength of the track at this point

Fig. 39.

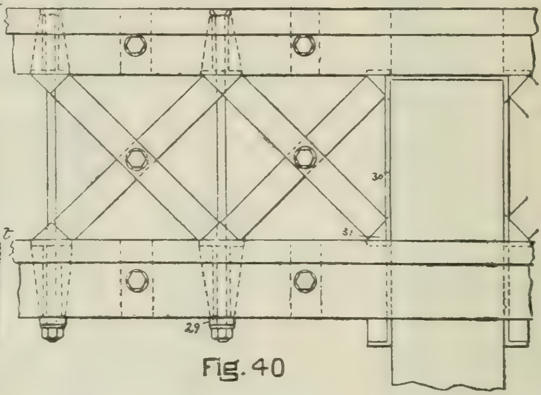


Fig. 40

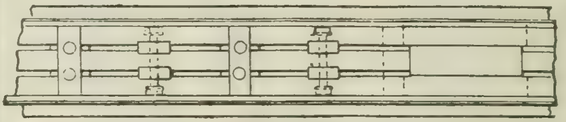
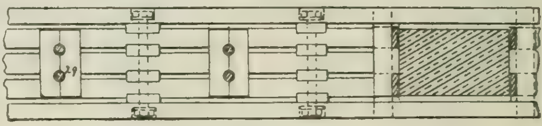


Fig. 41



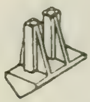


Fig. 42.

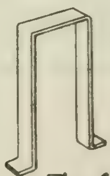


Fig. 43

Fig. 44

and yet form a hinge. In operating the switch, the first movement of the hand-wheel withdraws the locking spring-latch, d^9, from engagement with the girder, by means of the wedge-cam, d^8, and this device is also designed to be operated automatically by a moving train.

A singular effect of the inclined position or re-entrant angle of the truck wheels, described later on, has been found to be such that in running upon a switch left open even to the extent of fifteen inches, the switch will be closed by the train, thus increasing the safety of this feature.

The angle formed at the pivot or hinge end need never exceed 5°, for by dividing the throw of the switch equally to right and left of the centre line of main way, the length of switch truss required would not exceed thirty-five feet, which is a very moderate length.

IV. THE WOODEN WAY.

A form of construction for the permanent way of much less cost than that built entirely of iron, is illustrated in *Figs. 39–44.* It consists of a wooden Howe truss, *Figs. 39, 40* and *41*, which may be set on posts of any shape, *t t*, showing the rails as before. *Fig. 43* shows straps of wrought iron passing over the tops of the posts, upon which the lower beams of the compound girder are hung, being in this manner supported by the posts. *Figs. 42* and *44* are cast-iron chairs for the end bearings of the diagonal wooden braces of the truss. The trussing may be altogether dispensed with by placing the posts near enough together, as it may be a more economical construction in some cases to adopt.

(*To be continued.*)

THE RECENT TESTS OF INCANDESCENT LAMPS.

TO THE COMMITTEE ON PUBLICATIONS:

Under this title, Messrs Woodhouse & Rawson have published in several technical journals the following letter, which I take from the London *Electrician* of December 11, 1885:

THE RECENT INCANDESCENT LAMP TESTS.

TO THE EDITOR OF "THE ELECTRICIAN:"

SIR: It was not our intention to take any notice of the published results of the FRANKLIN INSTITUTE tests on incandescent lamps, as, considering the very strong comments that had been made on the subject in the various electrical papers, we thought it most unlikely that any one would be misled by them. We have, however, been advised that unscrupulous persons—more especially on the Continent—have been taking advantage of these tests to disparage our lamps. We shall therefore be glad, if you will allow us the opportunity of emphatically denying that any reliance is to be placed in them, and of placing the following facts before your readers.

We were advised by our agent in America to have nothing to do with the tests, as they would not be reliable, the Swan, Maxim, and other makers of incandescent lamps having refused to allow their lamps to be entered. We, therefore, decided not to compete. Lamps, however, stated to be ours, were entered without our knowledge or consent, half being actually supplied by the Edison Company, the chief competitors, and the rest being obtained from another electric lighting firm. Whilst being admittedly run at five volts above what they were labelled, giving out up to forty per cent. or fifty per cent. above the proper candle-power, they were placed in competition with lamps evidently most carefully made and tested beforehand.

As an example of the way in which the electrical press have treated the tests, we may call attention to the *Electrical Review* of America, dated June 13th, in which are given verbatim reports of interviews with the President and Secretary of the INSTITUTE, the latter stating that he refused to have anything to do with the incandescent lamp tests, because he did not believe in them. Another official of the INSTITUTE stated some three months ago that it was very doubtful if the tests could be seen by outsiders, as the tests themselves did not agree.

Whilst in many instances disagreeing with the methods adopted in the actual tests, we refrain from criticising them, as we are well aware of the many difficulties that have to be contended with. We merely add that we think that the INSTITUTE ought to have seen that we were properly protected and advised of what was going on.

We are glad to hear that there is some chance of complete tests being made in this country, when every precaution will be taken to ensure their being properly made. Yours, etc., WOODHOUSE & RAWSON.

In this letter, Messrs. Woodhouse & Rawson repeat a calumnious statement of a New York paper of June 13, 1885, but omit to add the contradiction by the Secretary of the FRANKLIN INSTITUTE, published in the following number of that paper, of June 20th, as follows:

[*From the Electrical Review, June 20, 1885.*]

ED. ELECTRICAL REVIEW:

My Dear Sir:—Do me the favor to correct in your next, what I take to be an unintentional mis-statement of my remarks regarding the "Electrical Tests," which appeared in last week's issue, and for which I must disclaim responsibility.

I stated to your representative, as I have invariably stated to numerous other inquirers, that I could give little or no information regarding them, and that the proper person to apply to for information was Mr. Tatham. Beyond this, I do not recognize the statements credited to me as my own.

Yours truly,

WILLIAM H. WAHL,
Sec'y Franklin Institute.

Philadelphia, June 16, 1885.

No other notice, as far as I know, was taken of the article, and the story died of its own absurdity.

The reason given by Messrs. W. & R. for reviving this defunct slander is, that rival makers of incandescent lamps are prodding them with the report of the judges appointed by the FRANKLIN INSTITUTE to test the efficiency and duration of incandescent lamps.

It is true that the Swan, the Maxim and other companies did not enter their lamps for the tests, for various reasons, but no one had any right or reason to apprehend that they would not be fair tests, and no one now has any reason to say they were not conducted fairly.

In the conduct of the tests, the cardinal principle was to do right, and also to avoid all appearance of wrong-doing.

To this end, a code was adopted and judges selected, with the full concurrence of the contestants, and nothing was concealed from the parties in interest. The contestants were invited to inspect and did inspect every step in the progress of the tests. Their experts compared the photometric measuring powers of the judges with their own.

I believe it would be impossible to find four men better equipped and experienced for their duties morally, mentally and physically, than the four judges of these tests.

I was a daily witness of their work, and weekly progress reports of the tests were made to the FRANKLIN INSTITUTE.

So much for the general indictment; and now for the particular complaint.

It is, *first*, that their lamps were tested without their knowledge or consent. *Second*, that their lamps were run at five volts above what they were labelled.

Two lots of their lamps were tested. The first lot, selected at random from a barrel of lamps belonging to the Van Depoele Company, were labelled 20 candles, 55 volts. They were tested and run at fifty-five volts. No. 9, with resistance cold of 106 ohms, lived longest, 715½ hours. No. 2, resistance cold, 102 ohms, exhibited phenomenal brilliancy.

The complaint that this lot of lamps was entered without their knowledge or consent, may be well founded.

The second lot of lamps was received through the Edison Com-

pany. I now learn that the origin of this transaction was as follows:

At a meeting of the London Society of Arts, held December 3, 1884, Mr. Wm. H. Preece, F. R. S., read a paper upon "Electric Illumination," in which appeared the following language [see *Journal of the Society of Arts*, December 5, 1884, page 73]:

"The efficiency of the glow lamps has also been very considerably affected by the improvement made, for instance, by Messrs. Woodhouse & Rawson and by Mr. Bernstein.

"The efficiency of the Edison lamps means the consumption of energy at the rate of five watts per candle, but lamps are now being made which give an efficiency of two and a-half watts per candle with an equal life, which is equivalent to an immediate reduction of fifty per cent. in the amount of energy required to maintain the system alight, and therefore in the cost of production."

Whereupon, the Edison Company challenged Mr. Preece to produce such lamps and have them tested by the FRANKLIN INSTITUTE, whose committee was preparing for the tests which afterwards were made.

Mr. Preece procured the lamps and forwarded them to the Edison Company, whose letter dated April 13, 1885, to Professor Marks (who acted as an executive committee), says: "Mr. Preece, the electrician of the English Post Office, has sent to Mr. Edison a number of Woodhouse & Rawson lamps. They are now in the New York Custom House. We have given directions to have them forwarded to you at the Electrical Exhibition in the original packing as soon as they are appraised."

At that time our test boxes were all occupied and our current employed.

Inside of the box when received, was found a large label addressed "for Mr. Wm. H. Preece, 20 candles, 50 volts." The usual label of Woodhouse & Rawson was on every lamp, altered however, so as to read as above, the figure 0 in the number 50 being written over an erasure. The resistances, cold, of all the lamps tested was nearly uniform, five at 100 ohms; two, each ninety-nine and 101 ohms, and one 102 ohms. [See Report, Table VI, page 38.]

These circumstances persuaded us that the lamps were not selected by chance.

They were tested and measured for horizontal and spherical efficiency upon the 7th May, both at fifty volts and at fifty-five volts with the results shown in the following table, which I have made up from the original records.

WOODHOUSE & RAWSON LAMPS. (Second lot.)

Measurements of Horizontal and Spherical Efficiency, at 50 Volts and at 55 Volts, Compared. Made May 7, 1885.

Lamp No.	Volts.	Ampères.	Watts.	Candles Averaged. Horizontal.	Candles Averaged. Spherical.	Watts per Spherical Candle	Watts per Horizontal Candle.
30	50·	1·071	53·75	14·19	11·48	4·68	3·79
	55·	1·167	64·18	22·73	18·52	3·46	2·82
31	50·	1·084	54·20	12·38	9·93	5·46	4·38
	55·05	1·182	65·07	20·93	17·28	3·76	3·11
32	50·03	1·084	54·23	12·43	10·47	5·18	4·36
	55·	1·195	65·72	21·28	17·36	3·78	3·09
33	50·	1·089	54·45	14·07	11·75	4·63	3·87
	55·05	1·188	65·40	22·67	19·01	3·44	2·88
34	50·03	1·050	52·53	12·52	10·34	5·08	4·20
	55·	1·147	63·08	20·78	16·91	3·73	3·04
35	49·95	1·046	52·25	14·48	11·73	4·45	3·61
	54·95	1·139	62·58	23·53	19·56	3·20	2·66
36	49·95	1·088	54·35	15·68	13·05	4·16	3·47
	55·	1·191	65·50	25·98	21·41	3·05	2·52
37	50·	1·086	54·33	13·88	11·51	4·72	3·91
	55·	1·185	65·17	22·93	18·74	3·47	2·84
38	50·05	1·097	54·90	12·24	10·05	5·46	4·49
	55·	1·197	65·77	20·70	17·84	3·69	3·18
39	50·	1·089	54·45	11·88	9·73	5·59	4·58
	55·	1·186	65·23	19·74	16·33	3·99	3·41
Average	50·	1·0784	53·944	13·375	11·004	4·941	4·066
Average	55·	1·1777	64·770	22·127	18·296	3·557	2·955

Upon discussing these preliminary results, the judges found it impossible to follow the label. Twenty candles illumination could not be had with fifty volts, and they decided to raise the electro-motive force for the following reasons: There are three points of excel-

lence in incandescent lamps--brilliancy, duration and economy. The boast for these lamps is that they are brilliant and cheap. It would not benefit their reputation to test them with fifty volts, at which the preliminary tests show that they are both dim and dear, for the sake of increasing their duration, of which the remaining time of the tests, about 300 hours, would furnish no proof.

In this decision the judges were governed by a desire to do for the lamps what they thought the makers would do if they had been present and aware of all the facts. The judges made no concealments of what they did, nor of their reasons for it. They published the results of the tests with fifty volts, but not prominently.

It was out of kind consideration for the makers of the lamps that the judges raised the electro-motive force, and it was out of a like consideration that they did not publish a table like the above.

These considerations, Messrs. Woodhouse & Rawson have trampled under their feet and have turned again to rend the committee.

I am unable to see the least shadow of unfairness in the proceedings of the judges, and I ask all those journals which have published the letter of Messrs. Woodhouse & Rawson to publish this reply.

I am, very respectfully,
W. P. TATHAM,
President of the FRANKLIN INSTITUTE.

ACTION OF LIGHT ON CHLOROPHYLL.—C. Timiriazeff experimented upon chlorophyll by Draper's method of decomposing portions of the previously dispersed light. His results show that chlorophyll acts as a true sensitizer, undergoing decomposition itself, and promoting the decomposition of carbonic anhydride in those parts of the spectrum which it absorbs. The different rays absorbed by chlorophyll produce decomposition in very different degrees, the maximum decomposition coinciding in a remarkable manner with the maximum energy in the normal spectrum as measured by Langley and Abney. It would seem, therefore, that it is the amplitude rather than the period of the vibrations which brings about that disturbance of the carbonic anhydride molecule which finally results in its dissociation. The chemical action of light on the photographic plate seems to be strictly analogous to its physiological action on the living plant, provided that, as in the case of chlorophyll, the absorption phenomena are identical in both cases.—*Jour. Chem. Soc., July, 1885.*

BOOK NOTICES.

THE WINDMILL AS A PRIME MOVER. By Alfred R. Wolff, M. E. New York: John Wiley & Sons, 1885.

Windmills are applicable only where a continuous power is not needed, or where it is possible to store up power for future use, but in these cases they are undoubtedly the most economical of prime movers. A complete treatise on this subject is therefore a welcome addition to mechanical literature.

In the above-mentioned treatise, the subject is well represented, both in its theoretical and practical bearings.

After a careful analysis of the dynamical effect of air projected upon flat surfaces, the theoretical results of the investigation are compared with those of other writers as well as with the results of actual tests.

A digest of the historical development of the windmill is followed by the detailed description of the principal modern constructions as made and used in this and other countries.

The comparisons of economy with other prime movers form a very interesting addendum, in showing the advantages, in this respect, of windmills.

H. B.

A TEXT-BOOK ON THE MECHANICS OF MATERIALS, AND OF BEAMS, COLUMNS AND SHAFTS. By Mansfield Merriman, Professor of Civil Engineering at Lehigh University. New York: John Wiley & Sons, 1885.

It is not here attempted to bring forward new facts or formulæ, but simply to give a clear and scholarly presentation of those already in use, with so much of explanation as the dignity of the young collegian can be expected to take without resentment; and this the author has admirably done. The book is precisely what its title indicates. It gives concisely, but fully, the laws governing the behavior of materials under stress, with brief statements of the average strengths, etc., of the substances in most general use, and is not cumbered with lengthy statistical tables, which, in such a book, would be out of place. It is written for young men at school, who have their mechanics at their fingers' ends, and the professor very properly draws upon their stock with considerable freedom. Still, the greater part of the work is available, and must prove very useful, to those practitioners who are not satisfied with merely having things right, but who who wish to refresh their recollection as to the "reason why."

The book is in good, clear type, and well printed, except the cuts, many of which are coarse and indistinctly lettered. There are but some sixteen fundamental formulæ, and the finding of these would be greatly facilitated by stating their *pages* in the references to them.

T.

THE ANEMOGEN.—Bishop Rougerie gives this name for an apparatus which produces air currents imitating the principal winds. It is composed of a small artificial terrestrial globe, rotating in the air and producing currents analogous to the trade winds, the equatorial calms, the variable winds, the reversal of the trade winds by the Southwest monsoon, as well as the ascending and descending currents at the poles, the equator and the regions of maximum barometric pressure.—*Comptes Rendus, Sept. 7, 1885.*

Franklin Institute.

[*Proceedings of the Annual Meeting, held Wednesday, January 20, 1886.*]

HALL OF THE INSTITUTE, January 20, 1886.

MR. WM. P. TATHAM, President, in the Chair.

Present—206 members and fourteen visitors.

Nineteen new members were reported as having been elected at the last meeting of the Board of Managers.

The President presented the Annual Report of the Board of Managers, approved at the Stated Meeting, held Wednesday, January 13, 1886:

ANNUAL REPORT OF THE BOARD OF MANAGERS FOR THE YEAR 1885.

The Board of Managers of the FRANKLIN INSTITUTE of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully present the following report of the operations of the INSTITUTE for the year 1885:

MEMBERS.

Number of new Members elected who have paid their dues,		198
Lost by death and resignation,	29	
Dropped for non-payment of dues,	45	
	—	74
		124
Total Membership at close of 1885,		2,257

FINANCIAL STATEMENT.

Receipts.

Balance on hand, January 1, 1885,		$6,929 80
Exhibition of 1884,	$3,575 10	
Exhibition of 1885,	42,000 00	
Temporary loan,	23,000 00	
New tests (returned)	50 07	
Editing Committee (Publication of Reports of Electrical Exhibition),	144 68	
Memorial library contributions,	650 00	
Other receipts,	13,573 08	
		82,992 93
		$89,922 73

Payments.

Exhibition, 1884,	$2,987 61		
Apparatus,	1,418 35		
		$4,405 96	
Exhibition of 1885,	$49,288 63		
Insurances,	1,836 50		
		51,125 13	
Competitive tests (electrical),		5,422 87	
Editing Committee of Electrical Exhibition, publication of reports,		1,836 50	
Temporary loan,	$8,000 00		
Interest,	177 45		
		8,177 45	
Cash in hands of Actuary,		420 00	
Other expenditures,		17,724 04	
			$89,111 95
Balance on hand December 31, 1885,			$810 78

It appears from the above statement that the INSTITUTE still owes $15,000 temporary loan, as against the value of the Exhibition property.

LIBRARY.

During the year 1885, the Library has continued to grow in the number of books and to improve as to their condition. The report of the Library Committee will show an addition of 6,280 books and pamphlets during the year. For the first time, the large collection of pamphlets belonging to the INSTITUTE has been classified and indexed, so as to be accessible to readers. This work is not yet finished. The continued effort to complete valuable serials has been successfully exerted. The increase to the Library has compelled the Committee to build up many of the cases to the ceiling and to stow out of sight, or remove to the upper floors of the building, many books which are seldom consulted. If we have no relief in the way of increased accommodation, it will soon be useless to make efforts to increase the number of books.

JOURNAL.

The JOURNAL has continued its usefulness. It has been very much enriched during the past year by the supplements added to each number, containing many valuable reports of the Electrical Exhibition, which will be referred to for many years to come. The general index remains unfinished.

LECTURES.

The following lectures were officially approved and delivered during the year 1885:

By Dr. N. A. Randolph, *two* lectures, on "The Chemistry of Nutrition;" Mr. C. J. Hexamer, *two*, on "Means for Extinguishing Fire," and on "Spontaneous Combustion;" Prof. E. J. Houston, *three*, on "Earthquakes and Volcanoes;" Prof. E. D. Cope, *one*, on "The Evolution of the Vertebrata;" Dr. Wm. H. Wahl, *one*, on "Electro-Metallurgy;" *one* by Prof. Thos. M. Drown, on "The Metallurgy of Iron;" *one* by Mr. Pedro G. Salom, on "The Metallurgy of Steel;" *one* by Prof. Geo. A. Koenig, on "The Metallurgy of Copper;" *one* by Dr. Henry F. Formad, on "The Present Status of the Germ Theory of Disease;" *five* by Mr. R. D. Baker, on "Elementary Chemistry;" *one* by Prof. Coleman Sellers, on "Scientific Method in the Workshop;" *one* by Lieut. Bradley A. Fiske, U. S. N., on "Electricity in Warfare;" *one* by Mr. Coleman Sellers, Jr., on "Oliver Evans and his Inventions;" *one* by Lieut. John P. Finley, U. S. Signal Corps, on "Tornado Study," etc.; *one* by Mr. A. H. Emery, on "Testing Machines as Instruments of Precision;" *three* by Dr. N. A. Randolph, on "Food, Nutrition and Digestion;" *one* by Wilfred Lewis, on "The Mechanical Powers," and *one* by Dr. Wm. H. Wahl, on "Water Gas."

The above list comprises twenty-eight lectures, most of which were illustrated. They were, as a rule, well attended, and a number of them have been deemed of sufficient importance to warrant their publication in the JOURNAL.

The plan of issuing *free* tickets, to members and others, admitting five minutes before 8 o'clock, was continued.

COMMITTEE ON SCIENCE AND THE ARTS.

This Committee, during the year 1885, reported upon thirty-two applications, in three of which they recommended the award of the Elliott Cresson medal; in ten, the award of the John Scott Legacy Premium and Medal (all of which were approved, respectively, by the INSTITUTE and by the Board of City Trusts); and in one case, a Certificate of Merit. Twenty-two applications are still pending before the Committee.

EXHIBITION.

The Exhibition of 1885 opened upon the 15th of September and continued until the end of October. Although it contained many exhibits of great value and originality, which ought to have been appreciated, it must be confessed that the attendance of visitors was less than had been hoped for. The valuable investments made for the purposes of this exhibition remain the property of the INSTITUTE, and will reduce the cost of holding another, if it should be determined to do so.

DRAWING SCHOOL.

The Board report the condition of the Drawing School as satisfactory.

The attendance at the Spring term, 1885, was	143
" " " Fall " "	190
Whole number, ...	333

The pupils, on finishing their course of instruction, are generally competent to engage as draughtsmen.

SECTIONS.

The Chemical and Electrical Sections of the INSTITUTE have displayed great activity, and their annual reports to be presented to the INSTITUTE, show large increase of membership and usefulness.

Respectfully submitted,

W. P. TATHAM, *President.*

Annual Reports of the Chemical, Electrical and Phonetic Sections, and of the Committee on Library, were read, accepted and referred for publication.*

The annual election, held this day, resulted in the choice of the following officers:

For President, (to serve one year,) CHAS. H. BANES; for Vice-President, (to serve three years,) FREDERICK GRAFF; for Secretary, (to serve one year,) WILLIAM H. WAHL; for Treasurer, (to serve one year,) SAMUEL SARTAIN; for Auditor, (to serve three years,) WILLIAM A. CHEYNEY; for Managers, (to serve three years,) GEORGE V. CRESSON, PERSIFOR FRAZER, WILLIAM HELME, EDWIN J. HOUSTON, ENOCH LEWIS, WILLIAM P. TATHAM, WILLIAM H. THORNE, JOHN J. WEAVER.

Mr. EUGENE H. COWLES read the paper of the evening, on "The Production of Aluminum and its Alloys in the Electric Furnace." (The paper and discussion thereon, appear in this impression of the JOURNAL.)

WILLIAM H. WAHL, *Secretary.*

VALUE OF THE OHM.—Mascart, De Nerville and Benoit have experimented, in accordance with the programme of the International Commission, in order to determine the dimensions of the mercury column at 0°, which represents the unit of electric resistance. The absolute resistance of a conducting circuit was measured by the quantity of induced electricity, which traversed it when it was displaced in the terrestrial magnetic field (Weber's first method), or when it was submitted to the action of a neighboring current (Kirchoff's method). The two methods employ the same instruments and have many common characteristics, which furnish the elements for a reciprocal check. The results by Kirchhoff's method agree the most closely and give the value for the ohm of 106·30 cm. The experiments by Weber's method, on the coil which was most carefully studied, give precisely the same value. The paper closes with the results obtained by different experimenters, the averages of the several methods being as follows: Permanent deviation of a magnet by a turning frame, 105·82; discharge induced in a frame for a rotation of 180°, 106·15; discharge induced by a current, 106·08; continuous induction current, 106·13; deadening magnets, 105·60; heat disengaged by a current, 106·22. Glazebrook, in 1882, obtained the value 106·29; Rowland and Kimball, in 1884, 106·31; Rowland, Kimball and Duncan, in 1884, 106·29.—*Ann. de Chim. et de Phys, Sept., 1885.*

---

* These reports will appear in the March number of the JOURNAL.

CHEVREUL.—Prof. Michel Eugene Chevreul, who recently entered upon his 100th year, is the first active scientific investigator who ever attained such an age, standing conspicuous for the vast amount of work he has done and for the great practical effect his work has had on the industries of the world. When Dumas, in 1852, addressed M. Chevreul, on the occasion of handing to him the prize accorded to him by the French Society for the Encouragement of National Industry, he said: "The prize announces the opinion of Europe upon works, which serve as models to all chemists; the results which are due to your discoveries, are counted by hundreds of millions." More recently, in 1873, the London Society of Arts awarded to him the Albert medal "for his chemical researches, especially in reference to saponification, dyeing, agriculture and natural history, which for more than half a century have exercised a wide influence on the industrial arts of the world." His scientific work, apart from its commercial outcome, was recognized by the Royal Society as far back as 1826, when he was elected a foreign associate. In 1857, the Copley medal was awarded to him. Other countries have also paid him honor, while the distinctions of his native land have showered upon him. He was born in 1786, at Angers, where his father was a physician of note. When only seventeen, he went to Paris to be assistant in the laboratory of the celebrated Vauquelin. His first chemical paper, which he published at the age of twenty, was followed in the next half dozen years by more than a score on different subjects. In 1813, he began a series of papers of "Chemical Researches upon Various Fatty Substances, and Particularly Upon Their Combinations with Alkalis," which extended for many years, and were afterwards rearranged in the volume "Fatty Substances." In 1824, he was appointed Professor of Chemistry at the famed factory of Gobelins, and the energy and untiring industry which were characteristic of his work soon accumulated stores of knowledge based on experiment. To exact experiment, he attached the highest importance. He wrote in 1823: "Experiment is not chemistry, facts alone do not constitute that science, but we cannot have discoveries without exact experiment." His "Researches in Dyeing" is an elaborate work, and his "Methods of Defining and Naming Colors" occupies the whole of vol. xxxiii, of the *Memoirs* of the French Institute. It has often been remarked that it is difficult to believe that the Chevreul of "Fatty Substances" fame and the Chevreul who wrote on colors, are one and the same man.—*Nature, Sept. 3, 1885.*

ALLOY OF COPPER AND MANGANESE.—A prize of 1,000 francs was awarded by the Société d'Encouragement to Pierre Manhès, for an alloy which contains seventy-five per cent. of copper and twenty-five per cent. of manganese. When a small quantity of this alloy is introduced into a mass of melted copper, it lays hold of the oxygen, forming manganese slags which can be easily removed. The operation is not costly, and it gives a pure metal with more resistance, tenacity and malleability than copper ordinarily possesses. Bronze, brass, and other alloys, are also greatly helped by this purification of the copper. It has also been shown by a series of experiments that the copper sheathing of vessels changes more slowly if it has been deoxidized by the cupro-manganese.—*Bulletin de la Société d'Encouragement, December, 1884.*

// JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXI. MARCH, 1886. No. 3.

COAL-TAR DISTILLATION.

BY PROF. SAMUEL P. SADTLER.

[*Concluded from Volume CXXI, page 110.*]

[*A Lecture delivered before the* FRANKLIN INSTITUTE *January 11, 1886.*]

The third case of the production of tar and ammonia as side-products, and of their recovery as residuals, is in connection with iron-blast furnace working, where raw coal is used as fuel. This has been recently attracting considerable attention among Scotch and English iron masters and to a very exhaustive article upon this subject by Mr. Wm. Jones, of the Langloan Iron Works,* where one of the processes to be mentioned is in operation, I am indebted for most of the facts to be stated. The coals used are the so-called Scotch splint coals, ultimate analyses of which show the following composition:

* Engineering, Oct. 16 and 23 and Nov. 6, 1885.

	Splint Coal, used at Gartsherrie.	Greenhill Splint Coal.	Rosehall Soft Coal, used at Langloan.	Hocking Valley Block Coal, (quoted before).
Carbon,	70·05	71·42	73·99	77·88
Hydrogen,	5·24	5·04	5·17	6·56
Oxygen,	12·08	10·40	10·52	10·57
Nitrogen,	1·36	1·46	1·32	1·51
Sulphur,	·75	·94	·54	·64
Ash,	3·80	2·24	4·10	2·84
Water,	6·72	8·50	4·36	. .
	100·00	100·00	100·00	100·00
Analyst,	Dr. Wallace.	Dr. Wallace.	Wm. Jones.	Lilienthal.

I have placed the ultimate analysis of the Hocking Valley block coal, quoted before, alongside of the Scotch coals for comparison. According to Jones, "Scotch splint coal contains on an average 40 per cent. of total volatile matters, of which 28 to 35 per cent. consists of tar, gas, etc., and they yield on an average 50 to 55 per cent. of fixed carbon. The conditions of the distillation in the blast furnace are rather different from ordinary retort distillation, or even coke-oven distillation." "We have the coal subjected in the first instance to a temperature of 600° to 700° F., and this temperature is a very gradually increasing one. Furthermore, the coal is being distilled in presence of oxide of iron and of gases rich in combined oxygen. Hence the enormous quantity of liquid products obtained from the coal, and the highly oxidized nature of the same." Mr. Jones states that, in his neighborhood, the temperature of the escaping gases is from 400° to 650° F., and the volume of gas per ton of coal averages 125,000 cubic feet at 60° F. "When we consider that this 125,000 cubic feet of gas leaves the furnace at 500° F., when it occupies a volume of over 230,000 cubic feet and that this gaseous volume is still further increased by 300 to 450 pounds weight of water per ton of coal, in the form of vapor at 500° F., arising principally from the oxygen of the coal and the water in the materials, and further that every ton of coal yields from 120 pounds to 220 pounds of tar, given off at this temperature partly as vapor and partly in a state of suspension, some idea is gained of the enormous gaseous volume per ton of coal issuing from the throat of a blast furnace, fed with raw coal."

The different principles and methods for the recovery of tar and ammonia from blast furnaces may be grouped as follows:

(I.) Methods depending on the condensation or cooling of the gas.

(*a.*) Alexander and McCosh process, or the Gartsherrie process.

(*b.*) Dempster process.

(*c.*) Henderson process.

(II.) Methods depending upon the use of acids without the cooling of the gas.

(*a.*) Neilson process, or Summerlee process.

(*b.*) Addie process, or Langloan process.

The Alexander and McCosh process is illustrated in *Fig. 5.* It depends upon the condensation or cooling of the gases, and the subsequent washing of the cold gases in towers or scrubbers. The gases from eight furnaces are collected in a main tube at the back seven feet in diameter over all. The gases are given a run of about 300 feet in this and a connecting tube, so as to allow them to deposit dust, and then enter the atmospheric condenser. This consists of 200 iron tubes 2½ feet in diameter and 40 feet in height, connected in pairs with a junction at the top and ranged in rows of ten. They are divided from each other by diaphragms in the usual way with a seven-inch seal. The whole apparatus stands on brick piers and the condensed products are run off to the storage pond by two seven-inch pipes provided with steam pipes to keep the thick tars as fluid as possible. Valves are placed at either end of this condenser. The temperature of the gases entering is from 300° to 400° Fahr., and they leave at 120° Fahr. The gases now enter the water condenser, consisting of a huge rectangular chamber, built of boiler plate. It is divided into seven chambers by iron diaphragms, open at the top and bottom, alternately to allow of the passage of the gases from one chamber to another. The water condenser is 45 feet in length, 18 feet in breadth and 45 feet in height, and is filled with three inch malleable iron tubes to the number of 2,700. These tubes are arranged in tiers and a current of water circulates through these tiers of tubes, the water travelling crosswise in an opposite direction to the gas. The water condenser stands on brick piers, and any condensed products are run off as before. Altogether about thirty gallons of water (natural

liquor) to the ton of coal are condensed from the gases, but the amount of tar condensed is comparatively small. The gases, now at a temperature of 60° to 70° Fahr., and under a suction of one and three-quarter inch water gauge enter the scrubber, which is 80

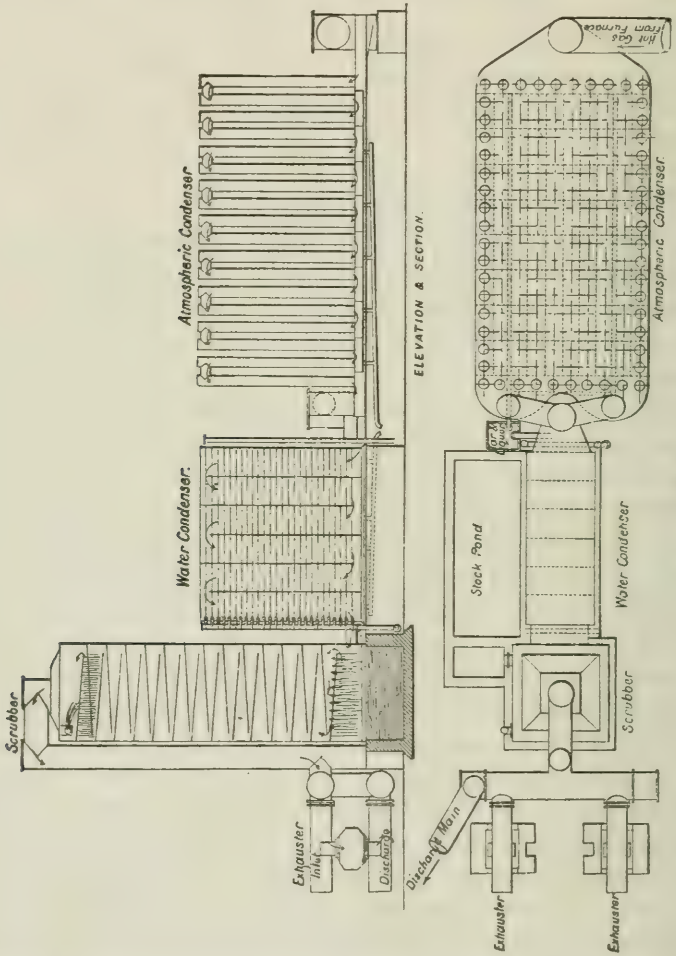
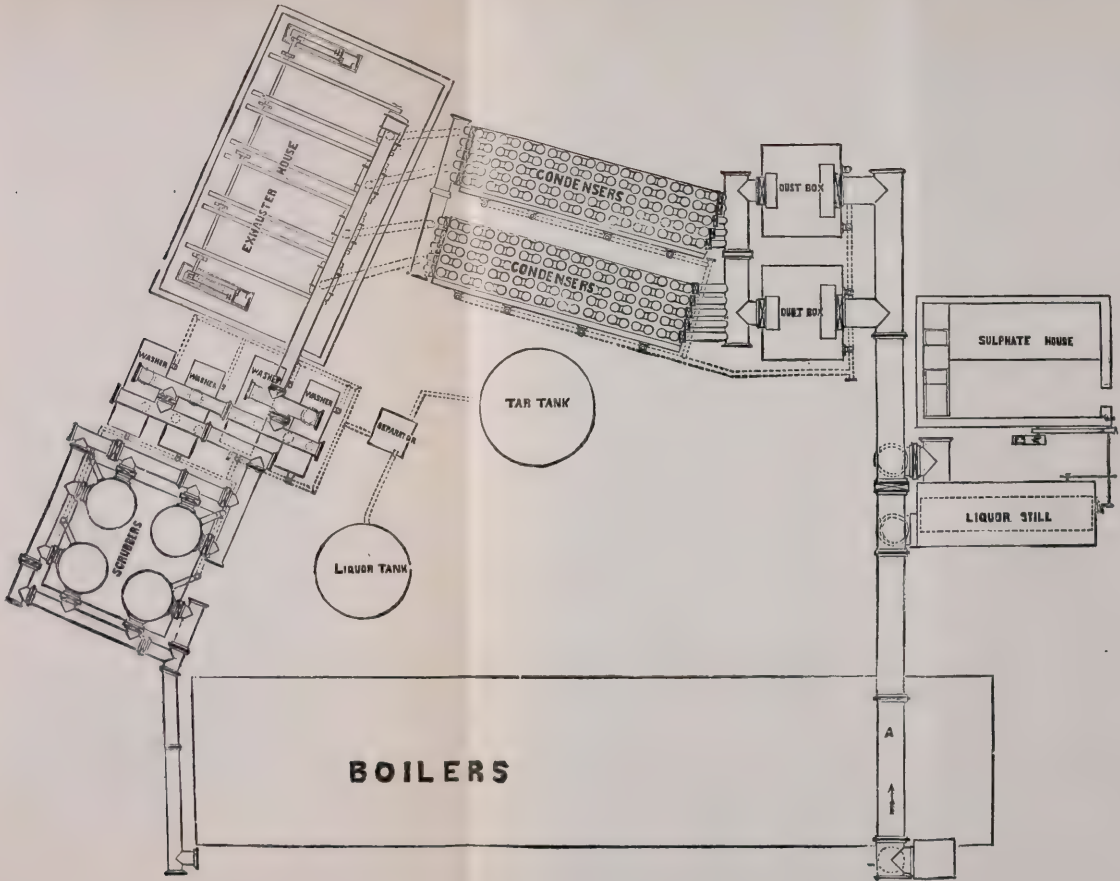
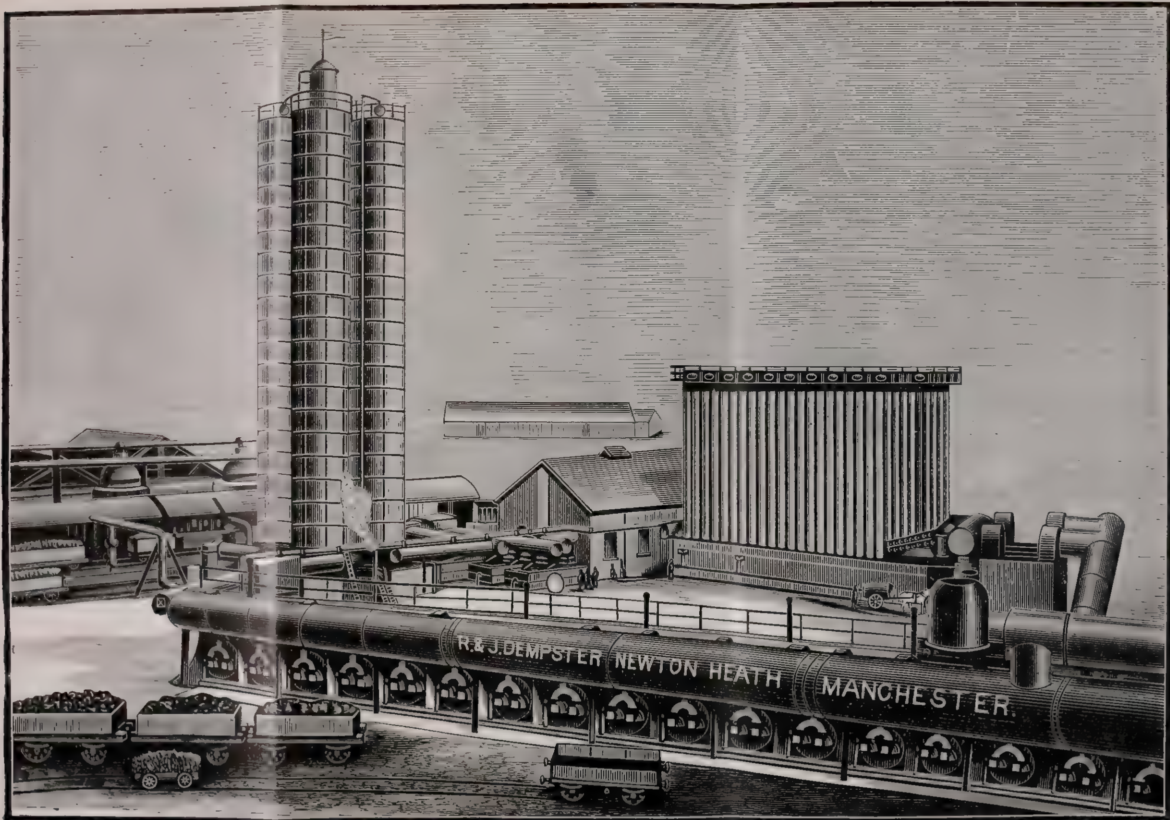


FIG. 5.

feet high and 25 feet square built of malleable iron plates three-eighths inch in thickness. It contains twenty-nine perforated diaphragms set at an angle. The scrubber is provided with explosion doors, a row of these being set opposite the end of each plate or diaphragm and serving for cleaning purposes as well.



EXHAUSTER HOUSE
CONDENSERS
CONDENSERS
DUST BOX
DUST BOX
SULPHATE HOUSE
WASHER
WASHER
WASHER
WASHER
SEPARATOR
TAR TANK
LIQUOR STILL
SCRUBBERS
LIQUOR TANK
A
BOILERS


R. & J. DEMPSTER NEWTON HEATH MANCHESTER.

The tar falls into a brick tank where it is separated as much as possible from the liquor. The gases are taken off at the top of the scrubber by a five foot tube, and travel to a second scrubber similar to the one described, but smaller. The greater proportion of the tar is caught in the first scrubber, but even at the second there is a very considerable amount of tar obtained, showing the great difficulty of washing the tar out of the gases. The second scrubber also washes the last traces of the ammonia out of the gas. The make of sulphate of ammonia at Gartsherrie was when the article of Mr. Jones was written, about thirty tons per week, equal to twenty-two to twenty-three pounds of sulphate of ammonia to the ton of coal. The make of tar is forty gallons to the ton of coal, this being equal to sixteen gallons of boiled tar to the ton of coal.

The Dempster process is illustrated by *Figs. 6* and *7*, of which the first gives a general view and the second a plan view. The gases are conveyed first to the ammonia still and the flues of this still are made three times the size of the other pipes. This is to cause the gases to flow slowly round the still and by reducing the speed to allow the dust to fall to the bottom of the flue. The temperature of the gases being much higher than the boiling point, the nitrogen from the liquor is driven off without any expense for fuel. As the still is large enough to hold about twenty-four hours' make of liquor, the liquor is twenty-four hours under the influence of the heat, and all nitrogen is driven off. The gases then flow on to what are termed dust boxes, which are to arrest the remaining dust that may have passed the flues of the ammonia still, but they are really washers, and most of the tar is given off in the water here. The gases at the outlet of the dust boxes are very much reduced in temperature and are then brought down to the temperature of the atmosphere by two pipe condensers. These consists of 100 wrought iron pipes, 40 feet long and 20 inches in diameter. The gases are then drawn through the exhausters which consist of four of Root's blowers driven by a pair of horizontal engines. Following the exhausters come four washers which are to take out the last traces of tar before the gas gets to the scrubbers. The four round scrubbers are 100 feet high and 12 feet in diameter and are filled with about 300 tons of wood boards and on the top of each of the first three scrubbers is an apparatus for distributing the

liquor over the boards. The last one has only clean water pumped through it. The gas then passes on to the boilers.

The third, or Henderson process is illustrated in *Fig. 8*. Our

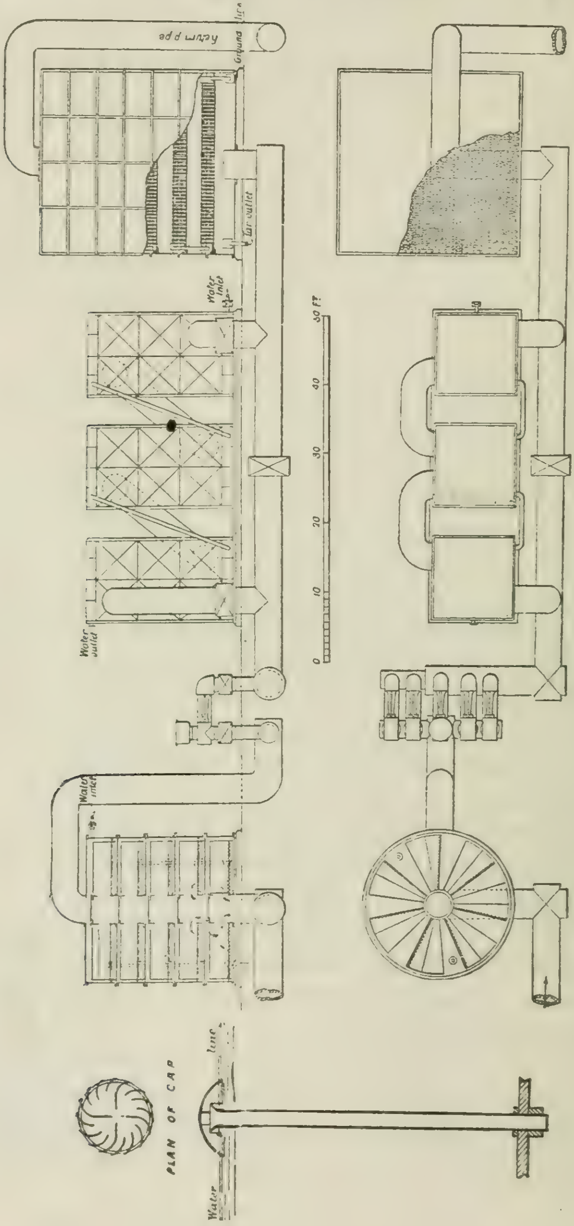


FIG. 8.

space will not allow of a detailed description of it. It includes (*a*) primary washer and cooler, (*b*) steam-jet exhauster, (*c*) slow speed water condenser, (*d*) a washer scrubber. A detailed description will be found in Mr. William Jones' article (*loc. cit.*).

The two remaining processes referred to, viz., the Neilson, or Summerlee process and the Addie or Langloan process both depend upon the absorption or fixing of the ammonia by acids combined with condensation or washing out of the tarry vapors. In the Neilson process figured in *Fig. 9*, this absorption

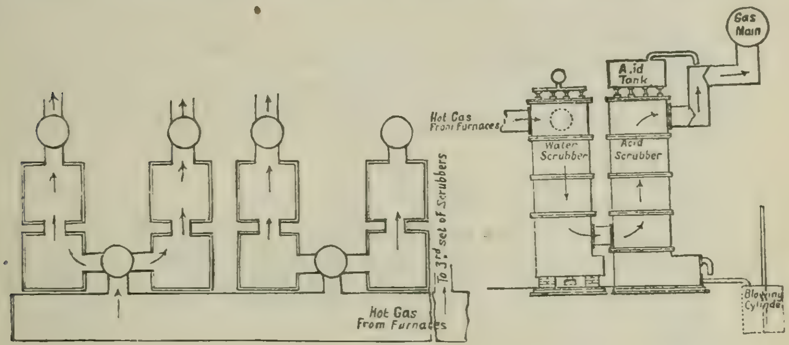


FIG. 9.

of the ammonia of the gases is effected by means of dilute sulphuric acid. A detailed description is given in Mr. Jones' article (*loc. cit.*). At the time of the writing of the article, the gases of two furnaces with about one-fourth of the gas from another were being handled and the make of sulphate of ammonia was from twelve to fourteen tons per week. In the Addie or Langloan process, sulphurous acid gas, made by burning "brasses" or sulphurous ironstone, is passed among the furnace gases in sufficient amount to combine with the ammonia and the gaseous mixture is subsequently washed in towers or scrubbers. It is illustrated in *Fig. 10*. In the apparatus as at present worked, the tar is not completely extracted. Mr. Jones (*loc. cit.*) states that, after passing through the apparatus, the gas is deprived of its ammonia but retains about forty per cent. of the tar which it originally contained. It is then distributed off to the heaters, boilers, etc., where it burns in the most satisfactory manner. The ammoniacal liquor obtained contains hyposulphite, acid sulphite and sulphate of ammonia. It is distilled with lime in ammonia stills like gas liquor and the ammonia freed and all con-

verted into sulphate. Plant is being erected at the Langloan works for the more thorough washing of the tars.

These blast-furnace tars contain no practicable amount of aromatic hydrocarbons and are free from anthracene. They are low temperature tars. The tars produced in the condensation methods contain from 30 to 42 per cent. of oil, while the tar from the hot washing processes contains from 20 to 25 per cent. of oil. The creosote oil from the Gartsherrie Works has a specific gravity of ·960 to ·980, and contains from 20 to 35 per cent. of phenols. The spirit or light oil from the Gartsherrie tars has a specific

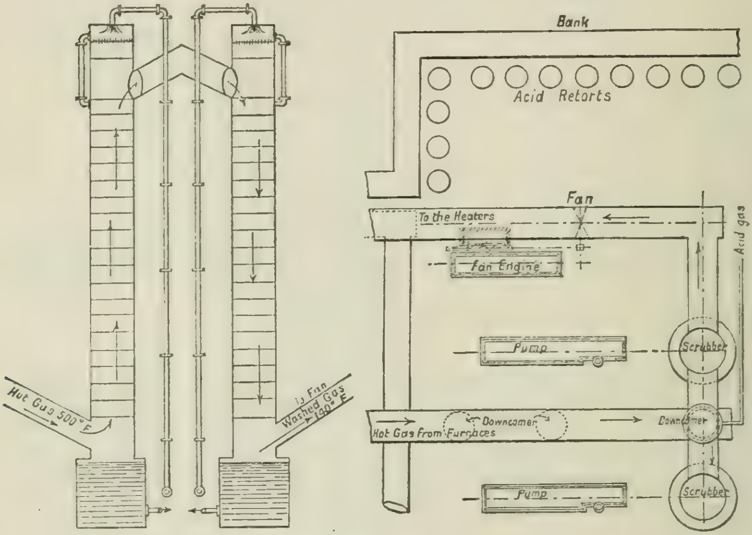


FIG. 10.

gravity of ·900 to ·910, and contains 15 to 20 per cent. of phenols Watson Smith obtains 23·1 per cent. of phenols from this variety of blast-furnace tar, as compared with about eight per cent. from Jameson coke tar, and 9 to 10 per cent. from gas retort coal-tar oil.

The fourth method of tar production was in connection with what are called "gas producers," of which a great number of forms, besides the well-known Siemens' producer, are known and used. In case the generators are fed with raw coal, we have, in addition to the formation of generator gas, a tar and ammonia production. This, it is true, is generally neglected, but it has in a few cases

been collected and some examination has been made of these residuals. Thus, the tar from the Sutherland gas producers, an English form of generator, has been chemically studied by Dr. Watson Smith. He found that its specific gravity was 1·085, being, unlike blast-furnace tar and the Jameson coke-oven tar oils, heavier than water, though only slightly. It is somewhat of the appearance and consistency of ordinary or gas retort coal-tar, but smells differently. It seems to be destitute of naphthas or spirit, which in some degree accounts for its higher specific gravity. The first distillation yielded the following percentages by weight of tar taken: Total oils, 36·9; coke obtained, 30·5; water and loss, 32·6. The oils were redistilled and yielded as final results lubricating oils, scale paraffin, some phenols, but no anthracene. The higher boiling oils show fluorescence, but not so much as similar oils from blast furnace tars.

The fifth and last method of tar production referred to, was in connection with the distillation of petroleum residues and the production of oil gas. We have already, in speaking of the conditions of destructive distillation, and the causes modifying it, referred to the results of Atterberg and Letny, and spoken of the character of the tar produced. In the case of Letny's experiments, in particular, we had petroleum residues destructively distilled with the production of tar, equal in amount to about forty per cent. of the oil taken.

Of oil gas methods, many have been brought forward, both in this country and abroad, but very little attention has been given to the liquid side-products of the distillation until recently. It is true that a thin liquid has been observed to condense in the holders where this oil gas is stored, especially when under some pressure. This was known to contain benzene and toluene. I had a sample of this light naphtha, as it was called, given me five or six years ago, taken here in this city from the drips of the reservoirs which supplied the oil gas for railway cars. But the thick tar formed in the processes of oil gas distillation has not been examined until recently. Prof. Henry E. Armstrong, of London, has examined two of these oil gas processes, the Pintsch and the Keith systems.

In the Pintsch system (*Fig. 11*), two cast iron D-shaped retorts are set one above the other, as shown in the figure, the largest size

in use being 6 feet 2 inches to 6 feet 4 inches long, 10 inches wide and $9\frac{3}{4}$ inches deep; the oil is run into the upper retort at one end, falling upon an iron tray which is loosely fitted into the

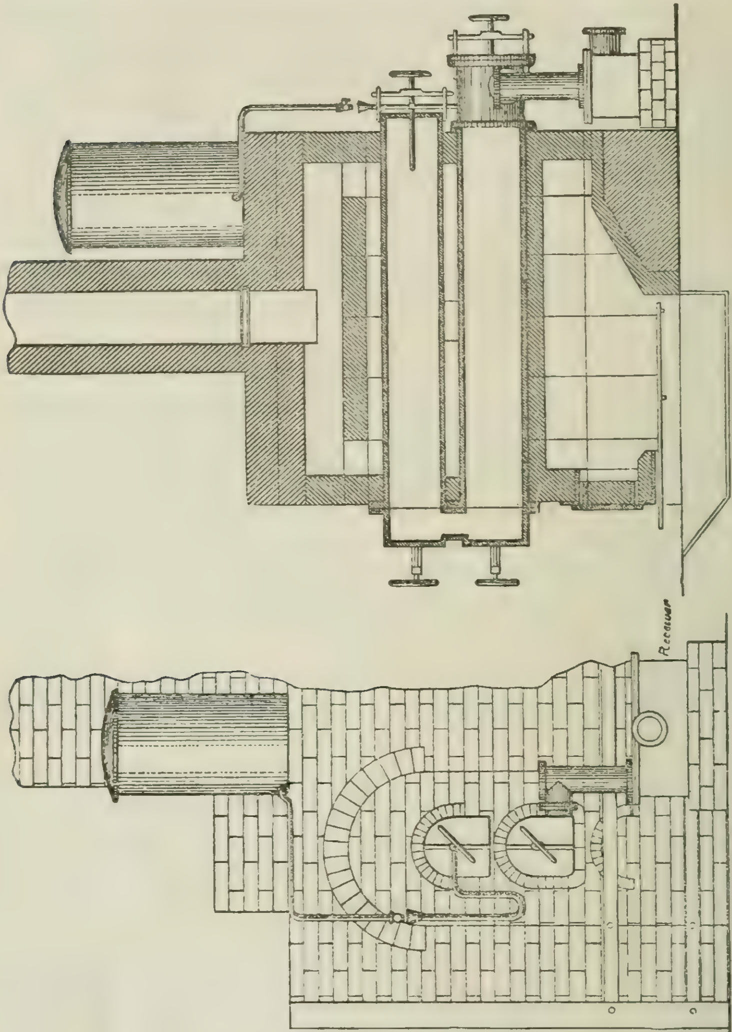


FIG. 11.

retort, and to complete the decomposition the vapors are passed into the second lower retort. The temperature at which the retorts are worked is very high—a bright cherry red. The oil may be run in at the rate of about twelve and a-half gallons per

hour. About eighty feet of gas per gallon of oil is reckoned a good yield.

The arrangement of the Keith plant will be obvious on inspec-

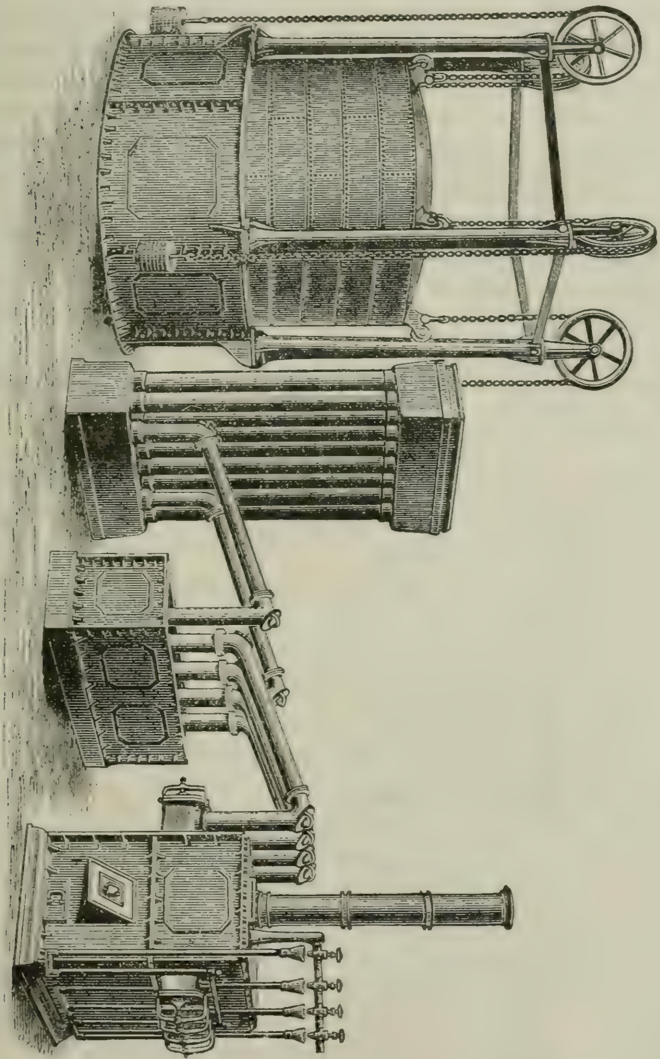


Fig. 12.

tion of *Fig. 12.* The retort is of peculiar form, being somewhat constricted in the middle. The largest size retort is 6 feet long, 5 inches broad, and 10 inches deep at the end; although shallow

in the middle, it is proportionally broader, so that the sectional area is the same as at the end. The oil is caused to flow down an inclined trough, not shown in the figure, so that it strikes the retort near the constriction, where the temperature is highest. It is stated that from 100 to 150 feet of gas may be obtained from one gallon of oil, according to the quality of the latter, and with twelve such retorts, it is expected that it will be possible to produce at least 2,000 feet per hour of not less than fifty candle-power gas.

" Pintsch gas is made by decomposing petroleum or shale oil and is compressed to about ten atmospheres; during compression, liquid is deposited in a chamber immediately attached to the pumps, and to a much larger extent in the reservoir in which the gas is stored and from which it is delivered into the iron recipients (drums) attached to the railway carriages; this liquid is commonly called 'hydrocarbon,' and it will be convenient to speak of 'pump hydrocarbon' and 'reservoir hydrocarbon.' A good deal of 'tar' is deposited from the gas prior to its collection in the gas holder."

The "hydrocarbon," as said before, contains benzene and toluene in abundance. Prof. Armstrong rarely found less than 50 per cent. of the two to be present. The tar from oil gas on the other hand is peculiar. Some specimens, examined by Prof. Armstrong, contained practically nothing that would volatilize in steam, and but the merest trace of naphthalene. It appeared to be all but free from aromatic hydrocarbons, such as occur in large quantity in ordinary tar, and to consist almost entirely of undecomposed petroleum hydrocarbons. Other specimens, however, contained benzene and naphthalene in appreciable quantity.

In the sample of tar yielding a fraction distilling with steam, Prof. Armstrong found hydrocarbons, apparently of the C_nH_{2n-2} series, such as Schorlemmer discovered in the light oils from cannel and boghead coal, and which are readily polymerised by sulphuric acid and yield no acid higher than acetic on oxidation. The three xylenes and mesitylene and pseudocumene are present in about the same relative proportions as in ordinary coal-tar; but, in addition, the oil-gas tar contains one—probably two—higher members of the benzene series. Naphthalene may be separated from the tar, and aromatic hydrocarbons of higher boiling point than naphthalene have also been obtained in small quantities. A

certain, though relatively small amount of a complex mixture of saturated hydrocarbons has also been separated from the tar; the quantity of material was quite small, but the author is inclined to believe that the mixture does not consist of paraffine, but of hydrocarbons of the C_nH_{2n} series—such as form the chief constituents of the Russian petroleum.

No examination has been made, as far as I know, of the tar from the Keith oil-gas manufacture.

We have thus pointed out how, in numerous other cases than in the process of manufacturing coal gas from bituminous coal, is it possible and even profitable to collect the tar and ammonia, which are formed at the same time as the gas and the coke as products of the destructive distillation. Indeed, there is no reason why these valuable materials should be lost sight of and despised as "residuals." As Prof. Armstrong has well said, "the time must come when coal-tar will not be regarded as a mere bye-product, and when attention will be paid, not only to the manufacture of gas, but also of coke and of *particular constituents* of coal-tar; when, in short, the materials latent in coal will be progressively utilized. It may be that then, the coal will first be coked, the oil which distils over being carefully condensed, and that the 'weak gas' thereby produced will be utilized as fuel; at the same time the ammonia and sulphur will be recovered. The paraffin, and whatever of immediate value it may contain, having been separated from the oil, the residue will be utilized in the production of oil gas and of benzene, anthracene," etc.

The possibilities of gaseous fuel are just beginning to attract attention and the uses of gases composed of hydrocarbons like natural gas, or of hydrogen and carbon monoxide like regenerator gases will probably extend greatly in the near future.

In presenting the possibilities of destructive distillation, I have looked almost exclusively at the amount and character of the tar produced. Much might be said, however, as to ammonia production, how it is affected by the conditions of the distillation and how it may be increased in amount and be properly extracted. That only a fraction of the nitrogen of the coal is obtained as ammonia in the aqueous distillate is universally conceded. Thus Mr. Wm. Foster (*Jour. Chem. Soc.*, London, 1883, pp. 105–110) finds that of the nitrogen of the coal, 14·50 per cent. is evolved as ammonia, 36·82

per cent. in the gas or tar, and 48·68 per cent. remain in the coke. Mr. George Beilby (*Jour. Soc. Chem. Ind.*, 1884, p. 216) states that when bituminous shales are distilled 17·0 per cent. of the nitrogen is found as ammonia in the watery distillate, 20·4 per cent. in the oil as alkaloidal tars, and 62·6 per cent. remain in the residue or coke. We have already shown that the temperature of distillation is one feature which affects the ammonia yield of any coal, high temperature destroying the ammonia first formed in the decomposition of the coal with the moisture present. If the distillation be pushed very slowly from low to high temperature by gradual stages, more ammonia can be gotten than when as in the gas retort process a very high temperature is used at once. Thus Beilby (*loc. cit.*) found that a slow distillation of this kind yielded instead of the result before quoted, 32·8 per cent. as ammonia in the watery distillate, 20·0 as alkaloids in the tar, and 45·7 per cent. in the coke.

But the development of the largest amount of ammonia from the nitrogen of a bituminous coal or shale seems to require the aid of steam acting upon the decomposing mineral or the coke as it is formed. Thus Mr. Beilby, using the same bituminous shales as yielded the results before quoted, (*loc. cit.*) by first distilling at a low red heat in an iron retort, and afterward subjecting the residual coke to the action of steam at a bright-red heat in a fire-clay retort, obtained of the nitrogen, as ammonia in the watery distillate 74·3 per cent., in the oil as alkaloidal tars 20·4 per cent., and remaining in the residue or coke 4·9 per cent. only.

Following on the same principle, Messrs. H. Simon and Watson Smith have patented a process (Eng. Pat., 4,871, Oct. 13, 1883,) for increasing the production of ammonia and its compounds during the process of making coke or gas. This they do by injecting into gas retorts, coke-ovens or gas producers, provided with arrangements for recovering by products steam along with hydrocarbons in a liquid or gaseous form. They claim that whilst the oxygen of the steam unites with the carbon, a portion of the hydrogen set free combines with the nitrogen of the partially decomposed coal forming ammonia, a portion also of the hydrogen unites with the sulphur of the fuel so that the quality of the coke is improved by the treatment.

With the present interest which is felt in the improvement of

our processes for treating coal and utilizing more fully its latent possibilities, we doubt not that much will be added to our knowledge of distillation methods and results in the near future.

THE DEVELOPMENT OF DYNAMIC ELECTRICITY.*

BY WILLIAM DENNIS MARKS,
Whitney Professor of Dynamical Engineering, University of Pennsylvania.

[*A Lecture delivered before the New York Academy of Science, December 25, 1885.*]

Electricity can, at our will, be converted into heat, light and motive-power. With all these capabilities, it lends itself in a wonderful way to the convenience of man, because of its ability to be led to the exact point at which we desire to use it, and can there be used at will in large or small quantities.

In short it possesses—

Facility of distribution;

Indefinitely great divisibility according to need; and

The ability to concentrate great power in a very small space.

I must limit myself, because of the brief time allotted, to the consideration of a small part of my subject, and even in this I will still further limit myself to the phenomena occurring on so considerable a scale as to be generally called engineering problems.

I will particularly call your attention to the conversion and reconversion of electrical energy into other forms of energy, in three ways:

(1.) The conversion of heat into electrical energy;

(2.) The conversion of electrical energy into light;

(3.) The conversion of electrical energy into mechanical energy.

THE CONVERSION OF HEAT INTO ELECTRICAL POWER.

The direct conversion of heat into electrical energy, has already had a partially successful, but not economical, solution in Clamond's stoves.

According to Cabanellas, a Clamond's stove consisting of 6,000 elements, and burning twenty-two pounds of coke per hour, will give a current of seven ampères, and 218 volts difference of potential.

---

* From advance sheets of the Transactions. Vol. V, No. 3, 1885–6.

Cabanellas also states that the amount of light obtained was equal to about 560 standard English candles.

This would give us nearly twenty-six candles per pound of coke. As we shall presently see, this is a result much less economical of fuel than can be obtained by the use of an engine and dynamo, under very unfavorable circumstances. The liability to derangement and the first cost of Clamond's Pile have prevented it from becoming commercially successful.*

Those of you who are familiar with electrical terms, will pardon me if I devote a small portion of our time to the endeavor to make their meaning clear to those who have given little time or thought to them, but are familiar with purely mechanical ideas.

The ohm, volt, and ampère are the practical British Association units used by electricians.

The legal ohm is the resistance of a column of mercury one square millimetre in cross section, and 106 centimetres in length, at the temperature of melting ice.

Ohm's law is

$$\text{Intensity of current} = \frac{\text{Diff. of Potential}}{\text{Resistance}}, \text{ or } I = \frac{E}{R},$$

from which you at once see that the resistance equals the ratio between the electro-motive force lost in the circuit, and the intensity of the current.

This is a constant for any solid so long as its form and temperature are not changed.

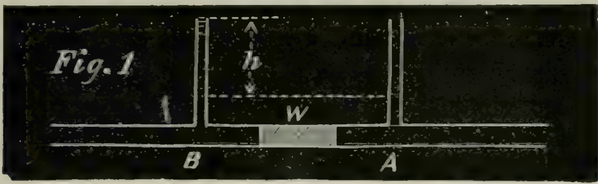
The volt, and ampère are more difficult to define, and perhaps I can best make their meaning clear by making use of analogous hydraulic formulæ.

Understand me, this is only a case of analogy. I do not say that electricity is a fluid, nor would I like to say that there is a current of electricity, or that it flows one way or the othor.

The volt may be said to represent the pressure or head of the assumed current of electricity, and the ampère to represent the intensity or weight of the current passing in one second. Lord Rayleigh has carefully determined the weight of silver precipitated

* These elementary explanations were made at the request of the Secretary of the New York Academy of Science, who requested me to endeavor to make my lecture "of interest to the general public by simple explanations." [W. D. M.]

from a solution of nitrate of silver by one ampère. It is 0·06708 grammes per minute, or 4·0248 grammes per hour.



Referring to *Fig. 1*, if W equals the weight of water that passes the point A in a pipe, in one second, and h the loss of head, we have for the work done in one second, $W\,h$ foot pounds.

Again, if I represents the intensity of a current passing the point A in a second, and E the difference of potential in volts between B and A, we have for the work done in one second $I\,E$ volt-ampères, or watts. If we divide $W\ h$ by 550 foot pounds we obtain the horse-power.

In the case of the pipe, if it were level, the loss of work would be due to friction, and transformed into heat.

$$\text{Thus } h = \frac{v^2}{2g} \text{ and } W\,h = \frac{W\,v^2}{2g} = \frac{M\,v^2}{2}.$$

Joule has shown us by experiment that the heating of a wire conductor is proportional to $I^2\,R = I\,E = \frac{E^2}{R}$, or using the analogous hydraulic formula, the heating is, $W^2 \times \frac{h}{W} = W\,h = \frac{h^2}{\frac{h}{W}}$

Again, $\frac{I\,E}{9{\cdot}81} =$ work per second in kilogrammetres, but an English horse-power equals 76·04 kilogrammetres per second, and, therefore, one horse-power $= \frac{I\,E}{745{\cdot}9}$. Returning again to the ohm, we have $R = \frac{E}{I}$. That is, the resistance is the loss of electro-motive force per second and per unit of intensity which an electrical current experiences when passing along a conductor. If this conductor is the standard quick-silver column, $R = 1$ ohm.

In an analogous manner we would say of a horizontal pipe con-

veying water, that the resistance is the loss of head per pound and per second, when passing through the pipe.

The resistance of the various materials used as conductors for the electrical current has been repeatedly and carefully determined.

I trust I have established a clear and cordial understanding of the terms which I shall need to use.

By the electro-motive force in volts, I mean something similar to the head of water in feet; or its pressure in pounds.

By the intensity of a current in ampères, I mean something similar to weight of water passing in pounds per second.

By the resistance in ohms, I mean something similar to the loss of head of water per pound and per second.

The dynamo-electric machine is the newest, and the most perfect of machines for the transformation of energy from one form to another. Like the turbine, its efficiency has been proved so great as to preclude all hope of further increase of practical value. Its cost may be reduced by improved processes of the machine shop, we cannot do more.

One reason for this rapid perfecting lies in the apparent obscurity of electrical phenomena, which has had the effect of repelling all but subtle and acute minds from their study. The right end of the thread once seized by such minds, they have followed the clue with such rapidity and thoroughness of apprehension as to leave nothing more for us to accomplish.

The recent experiments of the FRANKLIN INSTITUTE upon the dynamos of Weston and Edison have set the seal of absolute measurement, with a great exactitude as we can hope to reach, upon the ability of these machines to transform mechanical work into electrical work.

Of the five dynamo-electric machines which successfully withstood the severe conditions of the code, Weston's mammoth incandescent lamp machine, of a rated capacity of 125 ampères and 160 volts, returned as an average of four tests, in the form of electrical energy $96\frac{56}{100}$ per cent. of the mechanical power used to drive it. $89\frac{37}{100}$ per cent. of the mechanical power was available as electrical energy in the external circuit.

Of the total mechanical power applied, about one per cent. was lost in friction of the armature shaft, and resistance of the air to its rapid revolution.

Two and one-half per cent. only remains to be accounted for, and was presumably lost in the form of heat and eddy currents.

Every precaution was taken to avoid results which would not appear in every-day use, and all of the machines were run under full load for ten hours before the measurements began, and so were at as high a temperature as would be reached in actual practice with the same atmospheric temperature. The performance of this particular machine only exceeded the least efficient the machines tested by two and one-tenth per cent. total efficiency.

These results show that this high efficiency is not extraordinary, but is and should be attained by all dynamo makers building similar types.

In the case of the Weston (7 M.) dynamo, already specified, the power applied was distributed as follows in the first full load test:

Friction and wind resistance of armature, ...	·0106 total.
Electrical energy lost as heat in armature, . . .	·0559 "
" " " in creating field, ...	·0170 "
" " " in external circuit, . . .	·8992 "
Total of power accounted for, ...	·9827
Electrical energy lost in eddy currents, heat, and otherwise unaccounted for, ...	·0173
Total power as per dynamometer, ...	1·0000

This differs from the average already quoted, because slight variations of the conditions would cause any of the machines to vary somewhat in their percentages.

The greatest cause of uncertainty in experiments heretofore made upon the transformation of mechanical power, has been our lack of certainty of accuracy in the measurements of the mechanical power driving the machine. The dynamometer must sum up the whole power yielded to the dynamo with as great accuracy as is possible for all other measurements in part.

This dynamometer must be capable of being standardized by absolute measurement, and, after being standardized, the machines to be tested must be able to be attached to it or removed from it without altering the centres or adjustments of the dynamometer. It must be of great sensitiveness to small variations of load, while measuring large amounts of power with great steadiness.

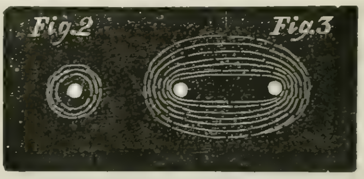
All of these conditions were fulfilled by the dynamometer invented by Mr. Wm. P. Tatham, President of the FRANKLIN INSTITUTE. Its extreme capacity is 100 horse-power, and yet, while making 1,040 revolutions per minute, carrying a load of twenty-nine horse-power, it was possible to measure with certainty the difference of power required by an Edison voltmeter requiring two-tenths of a horse-power. It announced at once the making and breaking of the circuit of this voltmeter, measuring the work lost in it with accuracy. Still other tests showed its capability to promptly register small changes of power while carrying great loads, and proved that the slight and rapid jar of the parts, due to a high speed, increased its sensitiveness of measurement.

Finally, this dynamometer was calibrated by the agitation of water, heating something over five tons of water through 15·5° Centigrade, giving, as the mechanical equivalent of heat, 772·81 foot pounds per British unit of heat (see Report).

While less can be claimed in the way of originality of apparatus or methods used in the electrical measurements of these tests, I trust that an examination of the precautions will convince you of the extreme care taken to obtain correct results. (See "Competitive Tests of Dynamo Electric Machines," JOURNAL FRANKLIN INSTITUTE, Nov., 1885.)

The dynamo-electric machine has grown out of the fact that, if we move a dead wire in the field of another fixed wire, through which a current is passing, the dead wire will have a current generated in it whose electro-motive force is proportional to, (1), the intensity of the current in the fixed wire; (2), to the velocity of motion of the moving wire, and (3), to the acting length of the moving wire.

If I take a single wire, *Fig. 2*, and pass a current through it, its field will resemble a whirlpool of which the wire is the centre.

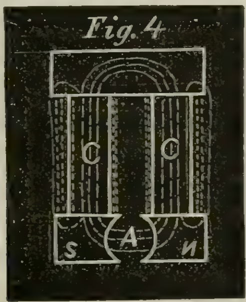


If I take two wires and place them a short distance apart, *Fig. 3*, and pass a current in the same direction through both, their

fields will combine to form an oval field, and any number of adjacent wires, with currents in the same direction, will do the same thing, forming a field of an intensity proportional to the number of wires and the intensity of the current in each. The field would, however, be of loose texture, so to say, and the lines of force far apart if the lines of force formed themselves around the wires in the air.

Iron, because of its great permeability to the lines of magnetic force, enables us to concentrate this field, and to place it, so to speak, where we desire to use it.

Pure, soft, wrought iron may be said to be 20,000 times more permeable than air.



You will see from *Fig. 4* what I mean. The wrought-iron cores *C* afford the easiest path for the lines of force, and they therefore follow them until they reach the armature space *A*, between *N* and *S*, where they take their airy path across, because the lines of force must always close.

We see that we have thus managed to concentrate the lines of the field of a large number of coils in a small space *A*. In this space the wires of the armature are revolved so as to generate a current which is either alternating, or approximately continuous.

The details of armatures and winding of them, as well as of the commutators, will be found described at considerable length in the works on "Dynamo Electric Machinery," written by Dr. Schellen, or Prof. S. P. Thompson.

I do not think that there is anything written better calculated to give the novice a clear idea of the principles involved in a continuous current machine, than Pacinotti's own description of his

machine, which can be found in the translation of Schellen, by Dr. Keith, on page 209.

I have shown you how perfectly the dynamo converts mechanical into electrical power, and I will now have to confess to you how exceedingly imperfect and irregular are the present methods of transformation of heat into mechanical power. Engines and boilers are both built in entire disregard of the actual principles of thermo-dynamics, and there has been so little accurate knowledge of the practical laws which should govern their construction, that makers, in many instances, shelter their wretched designs and workmanship behind the impossibility of predetermining the proportions which will realize the greatest economy of heat.

My own researches have convinced me of the impossibility of using small cylinders with any degree of economy of steam, unless they are compounded so as to permit between eight and ten expansions.

In the case of non-condensing engines, the boiler pressure should be about 135 to 140 pounds by the gauge, and in the case of all engines the speed should be as high as is consistent with safety.

Much of this waste is due to initial condensation of the steam on entering the steam cylinder, which was perceived by Watt, and partially remedied by him.

The quantitative law of this condensation, and its influence upon the most economical expansions of steam, I have endeavored to formulate in a paper in the JOURNAL OF THE FRANKLIN INSTITUTE for March, 1884, and showed, in the same journal, August, 1880, how narrow were the limits of Marriotte's law for the profitable expansion of steam, even neglecting the initial condensation.

Taking matters as they are, the most economical engine used for the purpose of driving dynamos at the late Electrical Exhibition of the FRANKLIN INSTITUTE required about thirty pounds of steam at ninety to 100 pounds pressure, and the most economical boiler evaporated about eight pounds of water per pound of anthracite coal at the same pressures. That is, an indicated horse-power required three and three-fourths pounds of average anthracite.

It can be assumed, with close approximation to average correctness, that fifteen per cent. of the indicated horse-power is lost in

the most direct method of transmission of power from engine to dynamo.

So we can say that one utilizable electrical horse-power per hour may, in good practice, be obtained from

$$\tfrac{3\cdot75}{85} \times \tfrac{100}{\cdot90} = 4\cdot\tfrac{90}{100} \text{ pounds of coal,}$$

(such as is sold in the open market as chestnut anthracite), and neglect the loss of electrical energy in the conductors.

The carbon equivalent of the coal used was ninety-one per cent. by weight.

Assuming 14,500 British units as the heat per pound of carbon, we have

$$4\cdot90 \times \cdot91 \times 14{,}500 = 64{,}655 \text{ British units of heat.}$$

Assuming the mechanical equivalent of one British unit as 774·1 foot pounds, we have very nearly 2,558 British units for one horse-power per hour. Dividing the last by the first we find that nearly four per cent. of the power latent in the coal appears as electrical power in the circuit. Ninety-six per cent. of our potential energy is lost; principally in the steam engine.

These facts, taken from the labors of many impartial and skilful workers in scientific research do not correspond with the alluring statements frequently set before us, but I believe them reliable and practical.

The broad lesson to be drawn from them is that we do not obtain one-twenty-fifth of the power in coal in the form of electricity; and that twenty-four-twenty-fifths remain to be obtained by the discoverer of an economical method of direct conversion of heat into electricity.

When the direct method of conversion of heat into electrical energy yields a larger percentage of the power in coal than the indirect method which I have just described, at the same cost, then will the dynamo supplant the steam engine. Until then it must remain what it is—a distributor of power for the steam engine, or other mechanical motor.

THE CONVERSION OF ELECTRICAL POWER INTO LIGHT.

There are at present in use two methods of converting electrical power into light. The first and apparently the most economical is by means of the voltaic arc between carbon points, the second, by means of the incandescence of a carbon filament in a vacuum.

The first method is open to severe criticism, save on the point of economy, and for lighting large spaces.

The briefest look at the intense spot of light formed by the arc between the points of carbon causes a painful and persistent image on the eye. The light has a vicious way of hissing, which becomes unendurable to sensitive nerves, and it varies the monotony of this noise by sudden jumps and flickers. Its ghastly effects are due to its bluish color and the deep, sharply-defined shadows.

In some cases the arc has a way of rotating around the axis of the carbons, which also causes variations of the intensity of the light in different directions.

Opal glass-globes, which cut off something more than one-half the light, are required to make the light tolerable; and as for the lamp itself, I do not think the greatest skill and taste of designers have yet rendered it ornamental when not lighted.

As a rule, the arc light is most intense when viewed at an angle of 45° from the vertical, and for this reason it is usually used for lighting open spaces from a considerable height I will assume its power as an average of the illumination at 30°, 45° and 60° from the vertical.

From the report on Electric Lamps of the FRANKLIN INSTITUTE, June, 1885, I take the following data:

Machine.	Angle with Vertical.	Candles.	Candles per El. H. P.	Average Candles per El. H. P.
Arago Disc, ...	30°	645	783	
	45°	583	708	
	60°	465	565	685
Ball, ...	30	182	421	
	45	485	1,123	
	60	520	1,204	916
Brush (1,200 c. p.), ...	30	355	762	
	45	613	1,316	
	60	537	1,152	1,076
Brush (2,000 c. p.), ...	30	1,200	1,529	
	45	1,373	1,750	
	60	1,082	1,379	1,553
Diehl, ...	30	887	1,176	
	45	830	1,101	
	60	725	961	1,079
Richter, ...	30	603	743	
	45	894	1,101	
	60	960	1,183	1,009
Van Depoele, 20 lights, ...	30	670	780	
	45	1,377	1,604	
	60	1,060	1,235	1,206
Van Depoele, 60 lights, ...	30	500	612	
	45	1,162	1,423	
	60	900	1,101	1,045
Western Electric, ...	30	75	121	
	45	266	431	
	60	355	575	376
	Average, ...			994

The average candles per electrical horse-power obtained from measurements upon the Arago disc, Ball, Brush, Diehl, Richter, Van Depoele, and Western electric machines was 994.

The efficiency of these arc-light machines was not obtained, but we are justified in assuming that seventy per cent. of the absorbed power should reappear as electrical power in the circuit, neglecting its losses.

That is, $\frac{3 \cdot 75}{\cdot 85 \times \cdot 70} = 6 \cdot 3$ pounds of ordinary anthracite coal per electrical horse-power per hour.

$$\frac{994}{6 \cdot 3} = 158 \text{ candles.}$$

If we divide the candles per electrical horse-power by the weight of coal required to produce them, we find in the arc system that we obtain 158 candles per pound of coal for the naked light, and something less than seventy-five candles if ground glass or opal globes are used, and the light seen from the most favorable position.

Very different from the arc light is the incandescent. Its light is so soft that we do not realize its brilliancy until we submit it to measurement. It gives out no products of combustion to poison our air; it shows colors truly. A delicate hair of carbon, sealed within a vacuum by walls of glass, glitters and glows until at almost limpid incandescence it gives us a steady, clear light, colorless as daylight.

If you will take a book and hold it from one to two yards away from a sixteen-candle light, you will find it sufficiently diffused to read with comfort.

Now all know that the intensity of illumination varies inversely as the square of the distance. Therefore, roughly estimating a shaded arc light at 500 candles, the same book would have to be held somewhere between five and one-half and eleven yards away from it to be read with equal comfort, assuming the light to be steady. We can then say that a sixteen-candle incandescent light will illuminate a circle of twelve and one-half square yards area, and that a shaded arc light giving 500 candles out of 994 will illuminate a circle of 400 square yards area, or thirty-two times as great. That is to say, about thirty-two sixteen-candle lamps would supply an equal illumination with a vastly better distribution of light for the use of the eyes.

We can, therefore, say that 500 candle-power from incandescent lamps will far more than replace 1,000 candle-power from the arc light, under the conditions, of actual usage.

We can safely say that, for all purposes save that of obtaining light to dispel darkness, the incandescent light is twice as valuable, light for light, as the arc light, and, therefore, should be multiplied by two when compared with it.

The objections most vehemently urged against incandescent lamps have been their short life and lack of economy; this is not true of them in all cases.

The first public test of the life of incandescent lamps was made by the FRANKLIN INSTITUTE in the early months of 1885 (JOURNAL OF THE FRANKLIN INSTITUTE, September, 1885.) The record of these tests is given in a pamphlet of some 130 pages, and with a detail which renders it impossible, in our limited time, to do more than gather from its averages such general lessons as we may learn.

From the efficiency test, which was preliminary to the prolonged duration test, we find that 194·1 spherical candles were realized per electrical horse-power.

	Spher. Candles.
Edison's 97 volt lamps—per El. H. P.,	169·2
Stanley's 96 " " " "	189·1
" 44 " " " "	216·1
Woodhouse & Rawson's 55 volt lamps—per El. H. P.,	209·0
" " " 55 " " " "	210·8
White's 50 volt lamps—per El. H. P.	182·6
Weston's 110½ volt lamps—per El. H. P.,	209·8
" 70 " " " "	166·3
Average, " "	194·1

The committee was forced by the different forms of carbon filament used to take the illuminating power of the lamps from all points, and to call the mean the spherical intensity of illumination. This procedure perhaps gives a better idea of the practical value of the incandescent lamp, because it is customary to place these lamps in any position that convenience may dictate.

I have already, I trust, convinced you that the incandescent lamp, by reason of its smaller quantity of light and better distribution, is worth at least twice as much as the arc light. I have also told you that one electrical horse-power costs with Weston's incandescent dynamo-electric machine, about 4·9 pounds of ordinary anthracite. Therefore, one pound of coal will give about forty candles by the incandescent lamp, and this is equivalent to eighty, and probably many more, candles by the arc light, whenever we have to use our eyes for any purpose save guarding our footsteps.

You will recall that under assumptions most favorable to the arc light, I showed you that we probably do not get more than seventy-five candles per pound of anthracite from the shaded arc

light. Had the Committee on Arc Lights obtained the spherical intensity of illumination of these lamps, their showing could have been made much less favorable than the one given. The present method of arc lighting must ultimately give way before the incandescent light, save for large spaces not requiring a close use of the eyes.

The low potential and larger current of the incandescent dynamos render necessary a lower resistance in the conductors, and so the cost of wiring for incandescent lamps is much greater, because of the increased weight of copper wire demanded to convey the current without too great a loss in the form of heat. This is the pecuniary obstacle, and about the only one that prevents the entire disappearance of the arc light before the incandescent light. Could an incandescent lamp be made of sufficiently high resistance to enable the use of high potentials, the last objection to the system would vanish. Who knows but that in a few days we may hear of its accomplishment?

The Edison ninety-seven volt lamps in this test, outlived all the others, demanded the least weight of conductors, and was thirteen per cent. less economical of power. It was the only lamp in the test that justified a claim to 1,000 hours of life.

Nineteen out of twenty lamps entered by this company survived a continuous test of 1,006 hours.

Mr. Weston entered a tamidine carbon lamp, intended to be used with 110½ volts, but imperfection of manufacture subsequently led him to pronounce them worthless.

The more successful lamps were found to undergo a process of gradual degradation which is attributable to two causes, an increase of the resistance of the carbon filament, and a deposit of carbon upon the interior of the glass of the lamp.

The discoloration of the various lamps was carefully compared after their life had ceased, and was remarkably deep in the case of the Woodhouse & Rawson, and the Stanley fourty-four volt lamps. Indeed, it would seem as if this discoloration was in some wise proportional to the economy of the lamp, as these two were the most economical of the makes of lamps entered.

A lamp may live a long time and yet be of little value for the purpose of giving light, because of this degradation. If you will take a lamp which has been used some time, and lay it upon a

white handkerchief, the gray coloring matter on the globe will be brought out quite distinctly.

Thus we see that great length of life with little usefulness may be attained by lamps. Indeed, the Edison lamps, which outlasted all others, had lost thirty-six per cent. of their illuminating power at the end of 1,006 hours.

Before turning to my last head, I will remind you that the direct conversion of heat into electrical energy by Clamond's stoves only produced twenty-six candle-power per pound of coke, as against forty candles per pound of anthracite in the usual way with incandescent lamps.

It will be a surprise to me should not the direct conversion of heat into electrical power prove to have quite as many difficulties, and as narrow limits as the conversion of heat into mechanical power by means of the steam engine.

THE CONVERSION OF ELECTRICAL POWER INTO MECHANICAL POWER.

The problem which just now is demanding of electricians their most earnest effort, is the transmission of work by means of electricity. This effort will be repaid by the utilization of otherwise inaccessible water-powers; and the problems of locomotion will have their simplest and least objectionable solution when it is an accomplished fact.

Marcel Deprez has recently transmitted sixty horse-power from Creil to Paris with a mechanical efficiency of fifty-three per cent.

The expense attendant upon an experiment of this magnitude has been very great, but the scientific possibility once proved, we can rely upon the progress of manufactures to reduce this expense, and to define the limits within which power can be economically delivered.

Seventy-five per cent. of the indicated power of the engine is not an overestimate of the power required to move the cable alone for our cable cars on a road of two or three miles length, but it would at once condemn an electric railway, which should be made to yield a practical efficiency of over fifty per cent.

Before discussing the details of the transmission of power, I will, with the aid of our previously used hypothetical fluid and

pipe, and with two pumps to represent the dynamo and motor, endeavor to make clear to you the laws controlling the transmission of power by electricity.

I must again remind you of the fact that I disclaim any knowledge of the real nature of electricity, and that I am reasoning from analogy alone.

Assume two pumps, *Fig. 5*, *A* and *B*, connected by a closed line of pipe so that the fluid must be pumped round a closed circuit. Let the pump *A* be driven by means of any external power. Let the pump *B* be reversed and acting as a motor. Let each of these pumps have a vertical stand-pipe projecting from its top, which will show the head *E* or *e* resulting from its action. The pump *A*

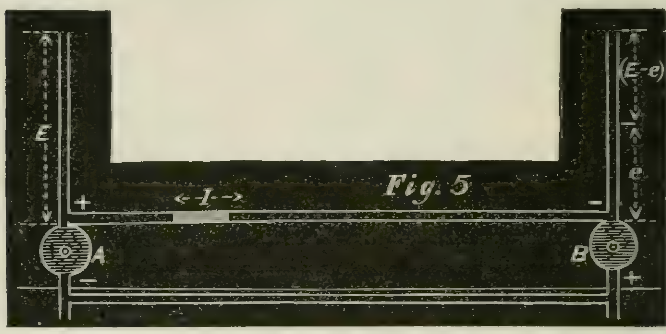


Fig. 5

acts under the law that its head *E* is proportional to the speed at which it is driven. The motor *B* acts under a similar law that its counterhead *e* is proportional to the speed at which it is allowed to run. The weight of fluid, per second, passing through the conduit, is directly proportional to the difference of these heads, and, inversely, to the resistance.

Let *I* equal the weight of fluid passing along the pipe each second.

The fluid passing along the pipes between *A* and *B*, and through the pumps, will lose, each second, a certain amount of head per unit of weight, because of the resistances.

Let *R* equal this resistance. Then we can say:

The weight of fluid per second is then directly proportional to the effective head, and inversely proportional to the resistance. This is Ohm's law, which, for electricity, is: *The intensity of the current is*

directly proportional to the difference of potential, and inversely as the resistance.

The loss of power, per second, in friction in the pipes, is the loss of head multiplied by the weight per second. This is Joule's law for loss in heat for electricity:

$$E\,I = \frac{E\,(E-e)}{R}, \quad R\,I^2 = \frac{(E-e)^2}{R}, \quad e\,I = \frac{e\,[E-e]}{R}$$

Work per second of pump A = Head $\times$ wt. per second.

" " " " " " $= E\,I = \dfrac{E\,(E-e)}{R}$

" " " lost in pipe $A\,B = I^2\,R = \dfrac{(E-e)^2}{R}$

R = head lost per unit of weight per second.

$$I = \frac{E-e}{R} \; \frac{\text{Weight}}{\text{per second}} = \left\{ \frac{\text{diff. head}}{\text{head lost per unit of wt. per second.}} \right\}$$

(Ohm's law.)

Work lost per second $= I\,(E-e) = \dfrac{(E-e)^2}{R} = I^2\,R$

(Joule's law).

Work per second of motor B = head $\times$ wt. per second.

" " " " " " $= e\;I = \dfrac{e(E-e)}{R}$

$$\text{Theoretical Efficiency} = \xi = \frac{e}{E}$$

Work of motor B per second a maximum for $e\,(E-e)$ maximum that is $e = \dfrac{E}{2}$

$$\text{Greatest work of motor } B = \frac{E^2}{4\,R}$$

" " Pump $A = \dfrac{E^2}{2\,R}$

The practical efficiency of this combination of pump and motor will be diminished because the head E will require a coefficient greater than unity, and the counterhead e a coefficient less than unity.

$$\xi = \frac{e\,(1-x)}{E(1+X)}$$

The value of $\frac{1 - x}{1 + X}$ must be determined by experiment.

It will at once be seen that when the motor is acting at its greatest horse-power the theoretical efficiency is fifty per cent., and its practical efficiency still less, for we must introduce $\frac{(1 - x)}{(1 + X)}$ as a factor of $\frac{e}{E}$.

On the other hand, if we increase the counter head e, the efficiency of the motor B increases proportionally, but the weight of fluid per second $\frac{E - e}{R}$ becomes less and less, and the work of the motor B per second decreases as $\frac{e\,(E - e)}{R}$ decreases.

But the work of the pump A per second also decreases as $\frac{E\,(E - e)}{R}$ decreases, and the lost work due to resistance to flow through pipe and pumps decreases as $\frac{(E - e)^2}{R}$ decreases.

It seems hardly necessary to call your attention to a misconception on the part of some, and I should not do so now had it not very recently come to my knowledge that a professor, claiming recognition as a high authority in electrical science, is still making the statement that the greatest possible efficiency of an electric motor is fifty per cent.

With a theoretical efficiency of fifty per cent. an electrical motor is doing the largest amount of work in horse-power of which it is capable, but it demands of the generating dynamo twice as much power as it gives out. With a greater theoretical efficiency, it does not turn out so much work per second, but it makes a demand of less than twice its work upon the generating dynamo.

This statement requires to be modified somewhat because of the imperfections of machines, and becomes more accurate in proportion to the perfection of the machines used.

This work lost in resistance of the pipe is plainly a minimum for $E = e$, and a maximum for $e = 0$ if R remains constant. Let us separate it into its component parts.

We see from the above equation that $\frac{(E - e)^2}{R} =$ constant,

when R varies as the square of the difference of the heads, or when the square root of R varies as the difference of heads.

If now we assume the resistance of the pumps as trifling in comparison with that of a long pipe or pipes connecting them, we see that we must double the difference of heads $(E - e)$ in order to have the same loss of work per second with a pipe four times as long.

Increasing the resistance four times gives us only one-quarter the weight of fluid per second assumed to be passing through the pipe, but doubling the difference of heads also doubles the weight of fluid per second, so that, under the altered conditions, we obtain one-half the weight of fluid per second, and twice the effective head. Therefore, the work per second lost in the pipe is

$$2\,(E - e) \times \tfrac{1}{2}\,\frac{(E - e)}{R} = \frac{(E - e)^2}{R}$$

as before.

The work done by the pump and motor, each working with twice its former head, remains the same as before, and their relative efficiency is the same.

This is what Marcel Deprez meant when he said:

"*The useful mechanical work and the efficiency remain the same whatever be the distance of transmission, provided the electro-motive forces, positive and negative, vary proportionately to the square root of the circuit's resistance.*"

I should like to emphatically call your attention to the deadly nature of the very high electro-motive forces demanded by this law, in the case of great distances.

One cannot but admire the boldness of this knight of science. In the face of mis-statement, based on erroneous assumptions, and of ridicule and opposition, in many cases becoming personal, he has adhered to his views and won his battle.

His detractors, while now forced to admit his results as correct, have shifted their argument from a scientific basis to a pecuniary one. One would think that so shrewd a financier as Baron Rothschild is not likely to be misled, and can safely afford to discount adverse editorial opinions, in the belief that a successful outcome will be reached before many years.

Let us hastily review the public experiments, which epitomize the results of his labors.

In 1881, at the Paris Electrical Exhibition, he exhibited in the Palace of Industry, one dynamo furnishing power to twenty-seven different pieces of apparatus. No measurements of efficiency were made, as the question of distribution was the only one then to be solved. He, however, then stated that it was possible to transport a useful work of ten horse-power thirty-one miles by means of an ordinary telegraph wire, with the expenditure of only sixteen horse-power on the generating dynamo, realizing sixty-two and one-half per cent. mechanical efficiency.

At the Munich Electrical Exhibition of 1882 over a line of telegraph wire thirty-six miles he obtained an electrical efficiency of thirty-nine per cent., and an actual mechanical efficiency of thirty per cent. In his experiments on the lines of the Chemin de fer du Nord, March 4, 1883, he transported 5·6 horse-power eight and one-half miles over ordinary telegraph wires, with 9·7 horse-power at the generating dynamo realizing an electrical efficiency of sixty-nine and one-half per cent., and a mechanical efficiency of fifty-eight and three-tenths per cent.

In his experiments, announced October 16, 1885, he obtained from his first, seventy-seven per cent. electrical, and forty-seven and seven-tenths per cent. mechanical efficiency. In the second experiment he obtained seventy-eight per cent. electrical and fifty-three and four-tenths mechanical efficiency by means of dynamometric measurements. The distance between these two points is fifty-six kilometres, about thirty-five miles. The speed of the generator varied from 170 to 190 times a minute, and there was no appreciable heating.

Tabulated results of experiments of Marcel Deprez—Convection of work between Creil and Paris:

	First Experiment.		Second Experiment.	
	Generator.	*Motor*	*Generator.*	*Motor.*
Turns per minute,	190	248	170	277
Diff. of potential,	5,469 Volts,	4,242	5,717 volts,	4,441
Current,	7·21 ampères,	7·21	7·20 ampères,	7·20
Work in field,	9·20 H. P.,	3·75	10·30	3·80
Work in armature,	53·59 "	41·44	55·90	43·40
Measured mech. work,	62·10 "	35·80	61·	40·
Electrical eff,	77 per cent.		78 per cent.	
Mechanical eff,	47 7-10 per cent.		53 4-10 per cent.	

Resistance of line, 100 ohms.

" " generator, thirty-three ohms.

" " motor, thirty-six ohms.

Diameter of copper wire = five millimetres.

$$\frac{35{\cdot}80}{62{\cdot}10 + 9{\cdot}20 + 3{\cdot}75} = \frac{35{\cdot}80}{75{\cdot}05} = 0{\cdot}477, \text{ for first experiment.}$$

$$\frac{40}{61 + 10{\cdot}30 + 3{\cdot}80} = \frac{40}{75{\cdot}1} = 0{\cdot}534, \text{ for second experiment.}$$

The labors of Marcel Deprez have both theoretically and practically opened the way and proved the entire feasibility of transporting great amounts of power for long distances. Much remains and will yet be accomplished in the way of cheapening the first cost of apparatus required, and also of rendering it automatic.

Perhaps the first condition to be placed upon a motor used in manufactures is that its speed shall be regular under all variations of load. Now, we know that with a constant field intensity H and length L, of armature wire, the speed V, and the counter electro-motive force e, vary together.

$$e = HLV \qquad \frac{e}{HL} = V = \text{constant.}$$

We see, then, that if we demand a constant speed and cannot vary the length of the armature wire, the intensity of the field must vary with the counter electro-motive force.

This can be accomplished by means of double enrollment, commonly called "compound winding," patented by Marcel Deprez, in 1881.

I have already explained to you how the lines of force of the field are led by iron cores, surrounded by coils of wire, to the spot where the armature, in revolving, can cut them. If the whole current generated in the armature is led through the coil around the magnet, and then through the external circuit, the winding is technically called series winding. If only a part of the current is taken off at the binding posts of the machine, and led through the coils around the magnet and back to the armature, the winding is technically called shunt winding.

The resistance of the shunt-wound magnet coils is usually much greater than the external circuit, but the number of turns also is greater, and so we attain a field of equal intensity.

Compound winding consists of the joint use of these two methods.

Mr. F. J. Sprague has recently (April 7, 1885,) patented a very clever combination of shunt and series winding for the purpose of

obtaining a constant speed of motion for a constant potential circuit, such as is ordinarily used for incandescent lighting.

$$\frac{e}{H} = \text{constant} = \frac{e_1}{H_1}$$

Let R_s = resistance of shunt field coils.
" N_s = number of turns of shunt field coils.
" R_d = resistance of series field coils.
" N_d = number of turns of series field coils.
" E = potential at terminals of motor.
" I = intensity of current through series coils.
" R = resistance of armature.

$E - R_d I$ = potential at shunt terminals = E_s.

$$\left.\begin{array}{l} \dfrac{E - R_d I}{R_s} = \text{ampères in shunt coils.} \\ \dfrac{E - R_d I - e}{R} = \text{" " armature.} \end{array}\right\} = \text{ampères in series coils.}$$

from the first equation we have

$$\frac{e}{N_s \dfrac{E_s}{R_s} - N_d \left[\dfrac{E_s - e}{R} - \dfrac{E_s}{R_s}\right]} = \frac{e_1}{N_s \dfrac{E_s}{R_s} - N_d \left[\dfrac{E_s - e_1}{R} - \dfrac{E_s}{R_s}\right]}$$

Eliminating $\dfrac{N_s}{N_d} = \dfrac{R + R_s}{R}$

The magnetizing currents in shunt and series windings are sent in opposite directions, and the number of shunt windings is to the number of series windings, as the sum of the resistances of the series windings and the armature is to the resistance of the armature.

This condition produces a magnetic field whose intensity is directly proportional to the counter electro-motive force, provided the magnets have not reached saturation.

Mr. Sprague, by ingenious devices, causes the currents to act together to start the motor with a very strong effort, and, once started, reverses one current and sets the contrary currents in the field coils to balancing each other, so as to produce a constant speed.

For constant potential circuits, this motor will not govern if its theoretical efficiency is less than fifty per cent. On the other hand, for constant current circuits such as are used for arc lighting,

this motor will not govern if the theoretical efficiency is greater than fifty per cent. We need not discuss it.

To avoid sparking at the brushes, Mr. Sprague has added a third series coil, which causes, in the case of dynamos having consequent poles, a counter distortion of the poles of the field magnet proportional to the increase of strength of the armature magnet.

Indeed, it would seem as if he had come very near realizing the ardent desire of all mechanics regarding their machines: "Once in order always in order." For economical reasons, motors running on arc circuits with a constant current, should have other methods of governing than the use of compound reversed coils.

Mr. Weston uses two methods for obtaining a constant speed. The first is by using belts upon reversed cone pulleys, which, with the aid of a centrifugal governor, shift so as to retain a constant speed for the driven machine, whatever be the variations of speed in the motor. The second is to vary the intensity of the field by means of resistance controlled by a governor or other automatic device. In our equation of condition for a constant speed, we observed two suggested methods of procuring this constant speed. The first was to vary the intensity of the field with the counter electro-motive force. The second was to vary the length of the wire in the armature coils.

This latter is manifestly impossible with the ordinary forms of machines, although it is not impossible that part of the field might be cut off, or the armature itself partially removed from a constant field.

Another way is to vary the counter electro-motive force of the motor by shifting the brushes around the commutator, but this is usually productive of sparking, and results in injury to both brushes and commutator.

The number of variations of this method is legion, and I would only weary you by recounting them.

For the purpose of locomotion, special arrangements to produce a uniform speed are not required. From all parts of the civilized world we learn the steady progress of the successful application of dynamic electricity to problems of locomotion.

In the transmission of power by electricity, the ends to be reached can well be stated under these heads:

(*A.*) Each receiving apparatus should receive its part of the

generated power, and, whatever be its action, should not influence other apparatus on the same circuit.

(*B.*) The efficiency must be independent of the number of apparatuses in action.

(*C.*) When a regular speed is desired, the regulation should be automatic and instantaneous, and should not require the intervention of an attendant.

Coming, as I do, from almost a year of unremitting experimental labor in a very small portion of the field I have this evening attempted to cover in an hour, I can only compare my lecture to an attempt to compress a bushel of solid matter into a quart measure.

I hope, however, that I have led you to believe with me that there is nothing of the mysterious left in the laws of dynamic electricity, and that with our thorough knowledge of its laws, a thousand heads, a thousand hands will make it transport to us at will heat, light, power, sound, sight, and chemical work.

MARKS: CORRECTION AND SUPPLEMENTARY FORMULA

THE LAW OF CONDENSATION OF STEAM.

JOURNAL OF THE FRANKLIN INSTITUTE, February, 1886, page 136, line 6 from the bottom, reads:

Dividing the condensation ·0125 by 3·80 and multiplying by 4·475, we have ·0146 for the corrected value.

Line 2, from the bottom, reads:

Dividing $C =$ ·0088 by 4·968 and multiplying by 8·22, we obtain ·0145.

For expansions greater than 2½ times, we can more accurately assume formula (7) JOURNAL OF THE FRANKLIN INSTITUTE, March, 1884, which is:

$$\text{Actual steam} = W_a = 62\tfrac{1}{2}\,\frac{e\,V}{S} + \left[(T_h - T_e)\,\frac{\pi\,d}{2\,N}\,(d - 2\,es)\right] C$$

to become

$$W_a = 62\tfrac{1}{2}\,\frac{e\,V}{S} + \left[(T_h - T_e)\,\frac{\pi\,d}{2\,N}\,(d - 1{\cdot}6\,e\,s)\right] C$$

This latter formula will give sufficiently accurate results for cut-offs not exceeding 0·4 stroke, but the general and accurate formula (9), JOURNAL OF THE FRANKLIN INSTITUTE, February, 1886, must be used for all later cut-offs.

RAPID TRANSIT AND ELEVATED RAILROADS, WITH A DESCRIPTION OF THE MEIGS ELEVATED RAILWAY SYSTEM.*

BY FRANCIS E. GALLOUPE, M. E., BOSTON, MASS.

[*Continued from Volume CXXI, page 149.*]

V. THE TRUCK.

The truck which has been found best adapted to the peculiar form of way has been designed and constructed as a development of the considerations governing the adoption of the permanent way. *Fig. 45* shows an end view, *Fig. 46* a side elevation, and *Fig. 47* the plan view. It consists of a horizontal rectangular wrought-iron frame, *1*, *Fig. 47*, stiffened by cast-iron pieces, *2*, *Figs. 45* and *47*, and provided with stiff cast pedestals, *4*, *5*, *6*, bolted to its under side, in which are fixed short axles for the wheels. The supporting wheels, *7*, of each truck are four in number and have a notched rim or right-angled groove which fits the angle-iron rail upon the upper corners of the lower track-stringers, being placed at an angular position of about 44° 50′ with the vertical, so as to run upon it, the axles being inclined.

Between the supporting wheels are two horizontal wheels, *8*, one on each side of the girder, upon vertical axles attached to the truck frame, and bearing upon the vertical rails on the upper track-beam of the girder. These move to a limited extent in sliding boxes, *q*, *Fig. 47*, to which their axles are affixed, are kept in yielding contact with the rails by springs outside the boxes and serve the purpose of balancing wheels to take side oscillations of the cars. They have flanges which lip under the lower edge of the rail-plates and thus tie the truck to the rails so that no lifting or jumping can take place, or the possibility occur of the trucks running off the track.

The truck wheels, which are large, being forty-two inches in diameter, yet light and strong, have a broad tread of three and one-half inches upon each bearing face, and rotate independently of each other upon large fixed axles, surrounded by a loose sleeve, which divides the friction. They are lubricated by oil, carried within the axles, which are hollow, so that the journals constantly run in a bath of oil, none of which can drop out by reason of caps tightly screwed over the hubs of the wheels upon the under side.

*A paper read at the Boston meeting, 1884, of the Amer. Soc. Mechanical Engineers, and reprinted from advance sheets of the *Transactions*.

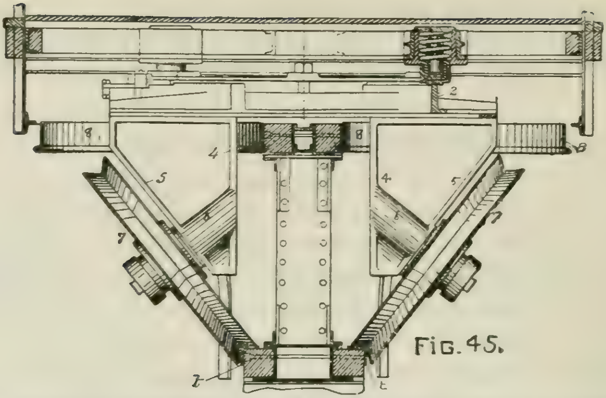


FIG. 45.

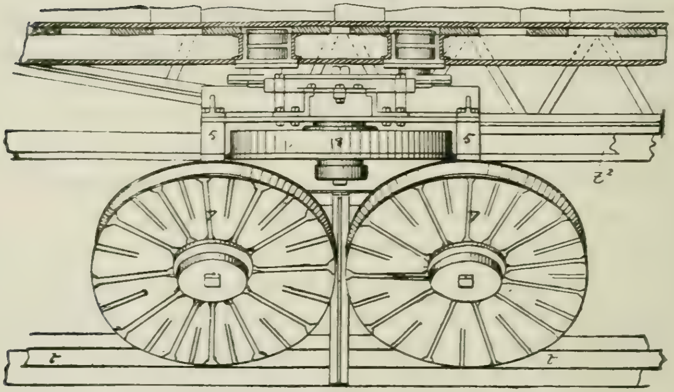


FIG. 46

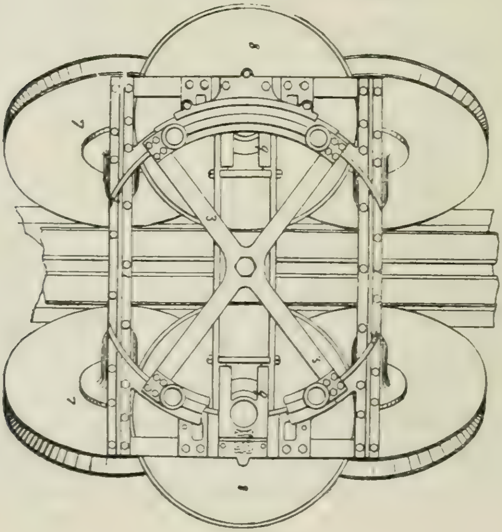


FIG. 47

Between the supporting wheels on either side of the girder are strong safety braces of **T** iron, extending from the pedestals, *5*, to points opposite yet so as to clear the rails by a small amount; and since the wrought-iron frame of the truck comes immediately above the girder, should any or all of the truck wheels break and even fall off, the frame would fall but about an inch before resting upon the girder, forming a strong shoe, which would slide upon, but could not leave the way, or allow the cars to overturn. That is, even in case of the breakage and absence of all the truck wheels, the framing alone could not leave the way, without lifting it through a space of over four feet, the entire depth of the girder, and this shoe is made sufficiently strong to maintain the cars, even then, in position upon the way.

Upon the top of the truck frame is a wrought-iron movable frame, *3*, *Fig. 47*, of segmental shape, carrying four spring posts containing heavy spiral springs, the posts interlocking beneath their upper flanges with similar spring boxes or sockets securely bolted into the floor framing of the car, which comes directly above the truck, within eighteen inches of the top of the girder. A centre-pin serves to guide the turning of the truck beneath this upper frame, and horizontal flanges of the truck frame castings overlap the periphery of the upper turn-table, thus as effectually tying the car body to the truck as the latter is tied to the rails.

The distance between the supporting wheels is four feet, which thus forms the rigid wheel-base of the truck, the trucks turning at curves and switch angles upon the balancing wheels placed centrally between them. Appliances for the transverse movement of the latter upon curves are also provided, which it will not be necessary to detail.

The theory of this truck is very simple, but yet has been found liable to constant misconceptions. To explain its principal features let it be conceived, in the diagram, *Fig. 51*, that *A* is a platform, assumed to be one foot in length perpendicular to the plane of the paper, loaded with an uniformly distributed weight of 4,000 pounds. Let *a a* be vertical posts supporting this platform, in the first instance, each of which posts would then sustain 2,000 pounds of load. Let *B* be a central post, and removing the posts *a a* substitute the diagonal braces or supports, *b b*. These diagonals now support the

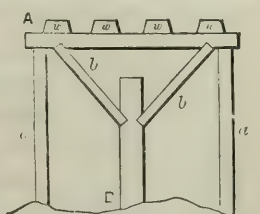


Fig. 51

same load as before, but the stresses in the braces *b b* will be greater than those in the former posts, *a a*, in proportion to the cosine of the angle that *b* makes with the vertical. For, the resultant resistance of the brace, *b*, acting opposite and equal to the stress due to the weight of the load, taking the direction and magnitude of the latter on any scale to be *A R*, *Fig. 52*, may be resolved into the two forces, *A a* and *A c* at right angles, *A c* producing an outward strain in the platform *A*, and *A a* being the component, in magnitude and direction due to the weight acting directly downward, or equal to 2,000 pounds. Hence it follows that the load in the direction *A R* is greater than that due to the weight, or *A a*; or

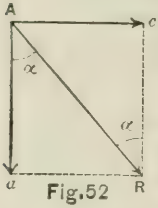


Fig. 52

$$A\ R = \frac{A\ a}{\sin \alpha} \text{ and } R = \frac{2{,}000}{\cdot 705047} = 2{,}837 \text{ pounds.}$$

Now, to support the weight upon a post and girder in this way, *B*, *Fig. 53*, being an end view of the way, a shouldered stick having a bearing against the upper rail at *a* may be used to carry the load, bearing upon a notched stick, *b*, at the other end, made to fit upon the lower rail at *c*, which would thus support the load. The resultant of the weight, *W*, acting downward upon one side of the posts will be to produce a downward pressure along the centre line of *b* upon the lower rail, *c*, and a horizontal pressure upon the upper at *a*. Now the supporting and balancing wheels of the truck are placed in precisely the positions these braces would occupy to support the load in the best manner upon this way. *Fig. 53* represents one-half, or one side of the truck. Of course the same thing would be true of the other side, and the leverage against the overturning of the car by any oscillations, unbalanced loads, or wind-pressure upon its side is represented by the depth of the girder, or distance between the rails *a* and *c* vertically, which is about four feet.

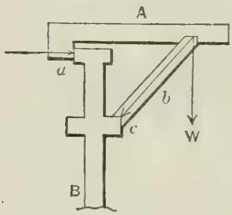


Fig. 53

The only difference is that in place of the fixed brace, with the wheels instead of the props a rolling brace is obtained, supporting the load wherever it exists, and removing so much heretofore necessary obstruction from the street by transferring it to the truck instead of allowing it to remain in the permanent way.

From what has been said it will be seen that the angle of the truck wheels will not necessarily be 45°, but dependent upon the proportions given to the permanent way. They are actually laid out as follows: Let *B*, *Fig. 54*, be an end view of the way, *a* and *c* the rails. From *a* as a centre with a radius *a c*, strike an arc *k c l*. Upon the same scale cut off a portion of the arc from *c*, with the chord *c d* equal to the middle diameter of the wheel. This chord will form with the vertical the proper angle to use for the wheel; and bisecting this, *b*, the position of the axle is found, which is maintained, together with the remaining bracing needed, in the construction of the truck frame itself.

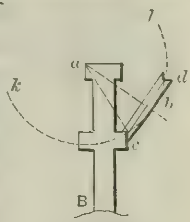


Fig. 54

For all loads, whether due to wind-pressure or centrifugal action upon the side *a*, or balanced or unbalanced loads acting downward upon the side *c*, press the wheels against the upper rail at the point *a*, about which the truck tends to turn, and the wheel, *b*, will transmit the force at right angles to the line *a b*, or directly through the centre line of the wheel *b c*.

With this construction there are no end strains upon the hubs of the wheels, since they are left free to move to a limited extent along the axles, being guided in position wholly by the lower rails. This allows the wheels to separate by sliding out upon the axles, should an obstruction, such as the protruding of a bolt-head, exist upon the track, while there can be no twisting strain brought upon the wheel or axle. For, from the fact that the wheel is guided and its position upon the axle determined entirely by the rail, there being no hub bearings, it follows that the bearing is always square upon the bottoms of the axles, and the effect of the load is thus communicated at all times directly down through the centre of the wheel to the rail. From this it results that all loads, balanced or unbalanced, aside from the weight of the wheel itself which of course bears upon the upper flange, are, when the truck is once properly proportioned, equally distributed over the vertical and horizontal surfaces of the lower rails. For, since the force of the load acting vertically downward may be resolved into two forces at right angles, one acting through the centre line of the wheel and the other along the axle, the wheel with no end bearings to the hubs would move until the latter component force becomes

balanced and neutralized, or, in other words, it would slide upon the axle until the pressure of the wheel upon the vertical and horizontal surfaces of the rail is equalized.

Besides the increase of load due to the inclination of the wheels, there appears to be but one other mechanical objection to the construction. Because of the varying diameters of the wheels at dif-

FIG. 50 FIG. 49

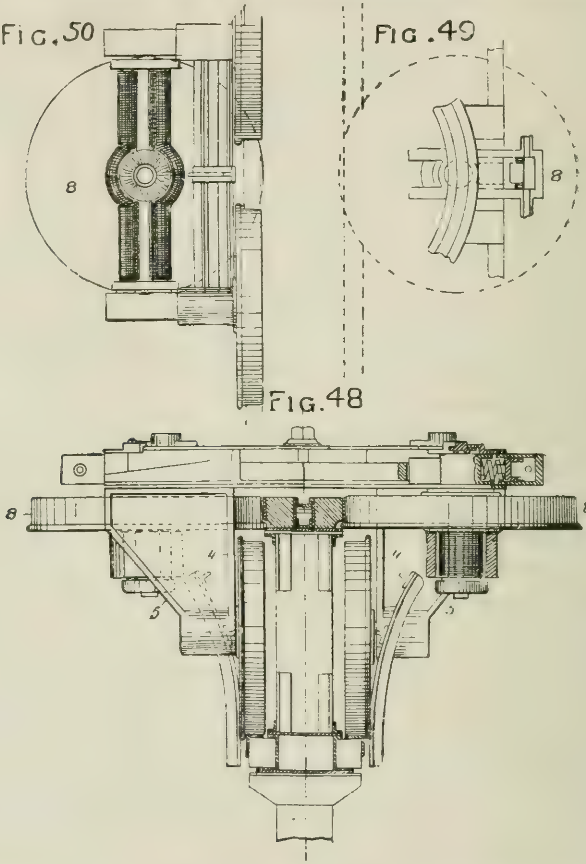


FIG. 48

ferent distances from the centre line there will be a slip of the rims in every revolution equal to the distance they will travel in a revolution beyond that of the central element. This will probably not prove more objectionable than the present flange friction existing upon railroads, and may be improved by slightly flaring the grooves upon the sides so as to bring the bearing principally near

the central portion of the wheel rim. It may be entirely avoided by the use of ordinary rails placed at the proper angle, and providing the wheels with a flat tread at right angles to the centre line, with double flanges upon the edges.

By reason of the independent motion of all the truck wheels, which is rendered practicable only because the design of the truck prevents the possibility of derailment from any cause short of the destruction of the way, curves are followed so closely that, practically, the increase of friction of the cars upon curves even as small as fifty feet radius, is too slight to be noticed or measured by weighing in a model one-eighth of full size. The construction also admits of a car fifty feet in length turning by means of these trucks from a street but twenty-eight feet wide into another of the same width.

In *Figs. 48–50* is shown an alternative plan of construction for the truck. It is provided with vertical instead of inclined supporting wheels having flanges upon their outer rims, and is designed especially with a view to the use of electricity as a motive-power. *Fig. 50* shows a dynamo-motor for

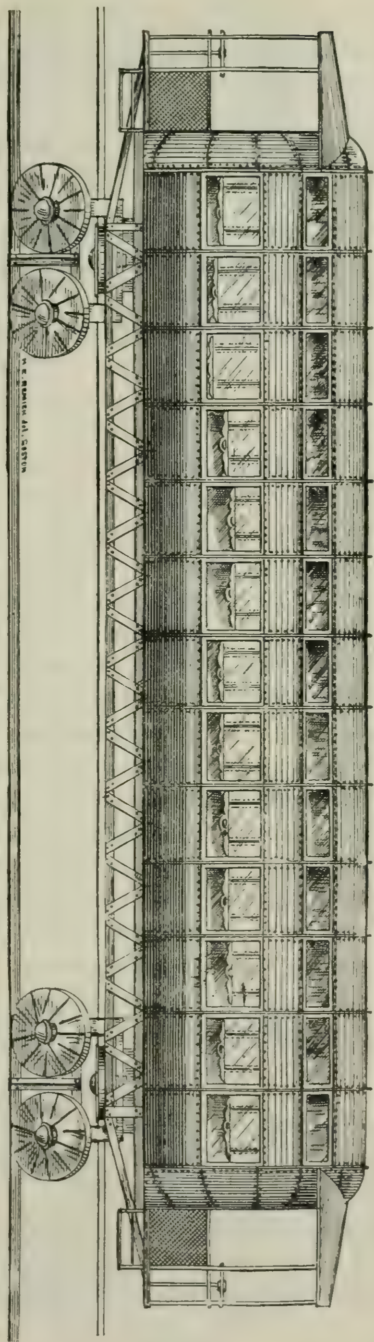


Fig. 55. Scale 1/8" = 10'

the truck and car, the electric current in this case being derived from the rails, which are insulated from the girder for the purpose, expansion being provided for by cables at the slip joints of the posts. The motive-power is conveyed to the truck and cars through the horizontal wheels, which act as the driving wheels.

VI. THE PASSENGER CAR.

The car designed by Captain Meigs is novel in many of its features. An outside view, end view, and cross-section are illustrated in *Figs. 55, 56* and *57*. It consists of a strong well framed platform built of 5-inch channel beams, 7 feet 6 inches in width by 51 feet 2 inches in length over all, attached to the trucks by four interlocking spring posts at either end. The body framing is composed of light **T** iron ribs, circular in form, filled in by panels covered with upholstering, which covers the entire interior, and sheathed with paper and copper upon the exterior. The car is perfectly cylindrical above the floor, 10 feet 8½ inches in diameter, inclosing the same cross-sectional area as the standard car in use. The construction is made as light as possible, and strength of form carefully studied. The cylindrical shape is expected to diminish wind resistances and stresses fully one-third as compared with the ordinary car. The seats or chairs, fifty-two in number, are arranged as in parlor cars, *i. e.*, independent, revolving, and also automatically folding up to gain space when unoccupied. They, like the whole interior of the car, except the windows, are upholstered, and comfort and luxury has been studied in every detail. The chairs, as well as the device or securing ventilation at each window without the annoyance of entering dust, are new and special devices of the inventor. If it were ever desirable, one would become more easily reconciled to rolling down an embankment in one of these cars than in that of any other known form, for the entire absence of sharp corners and salient points is noticeable.

VII. THE ENGINE.

The engine or locomotive for this system comprises a platform car supported upon two trucks, one at either end, housed in similar manner in all respects to that of the passenger car. Its general appearance and principle working parts are shown in *Figs. 58, 59*, and *60*, in outside view of engine and tender coupled, a front view of the engine, and plan of engine floor with the locomotive mechan-

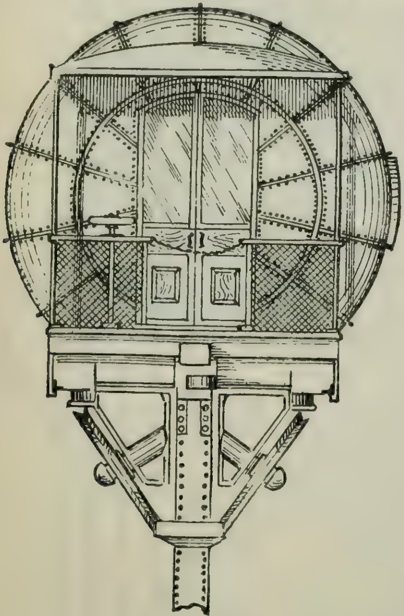


Fig. 56.

Scale $3/16'' = 1'$

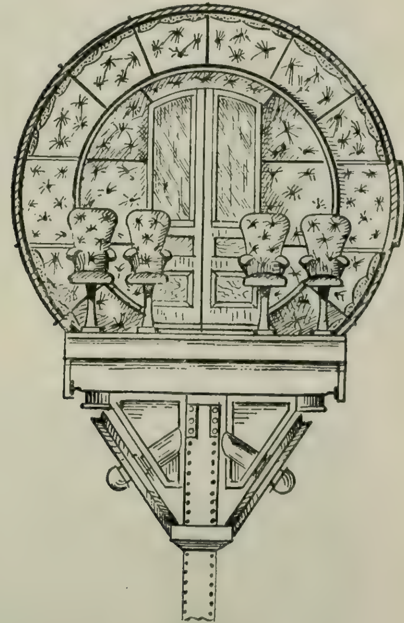


Fig. 57.

ism and boiler upon it, the position of the latter being shown by broken lines. The engine floor is 7 feet 6 inches in width and 29 feet 3 inches in extreme length ; that of the tender, carrying tank and bin for the water and coal, being 25 feet 8 inches in length, allowing additional room for baggage or the transportation of employés, or for other purposes. Upon this floor in the engine, covered with one-quarter-inch iron plates, in effect two complete stationary engines are supported, each connected to and operating a single driving wheel, the pair being horizontal in position and opposite each other on either side of the upper track-beam of the girder and midway between the trucks.

A boiler of the locomotive type, though shorter, being 60 inches in diameter of shell, and 15 feet in length over all, is placed over the engine mechanism, its centre line being 61 inches above the floor. It contains about 200 tubes, 2 inches in outside diameter and 7 feet long, with a grate 4 feet 6 inches square, containing 20·25 square feet area. For city use anthracite coal will be used for fuel. The crown sheet is arched or elliptical in shape, stayed to the outer shell by radiating stay rods, and is inclined downward four inches at the back end, to allow of the climbing and descending of grades equal to 800 feet to the mile, without exposing any portion uncovered by water to the furnace fire.

The cylinders, 12 inches in diameter by 22 inch stroke, are horizontal, their centre lines placed 18 inches above the floor of the engine and 61½ inches apart. The piston rods connect with independent cross-heads sliding upon steel guide rods 2½ inches in diameter and 22 inches centres, these being supported at their ends by cast-iron standards bolted to the floor beams.

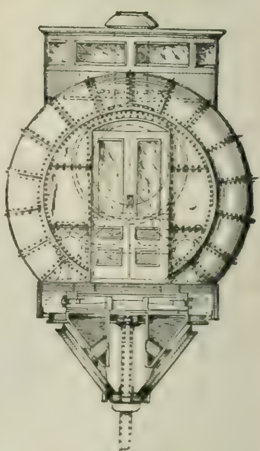


Fig 59.

The driving-wheels, 44·6 inches in diameter, flanged upon their lower edge, in form and position similar to the balance wheels of the trucks, are supported and rotate upon short stout axles of steel, six inches in diameter, which extend through a sliding-box containing the journals. These boxes slide in cast-iron ways transversely to the longitudinal line of the engine, the axle having a crank keyed upon its upper

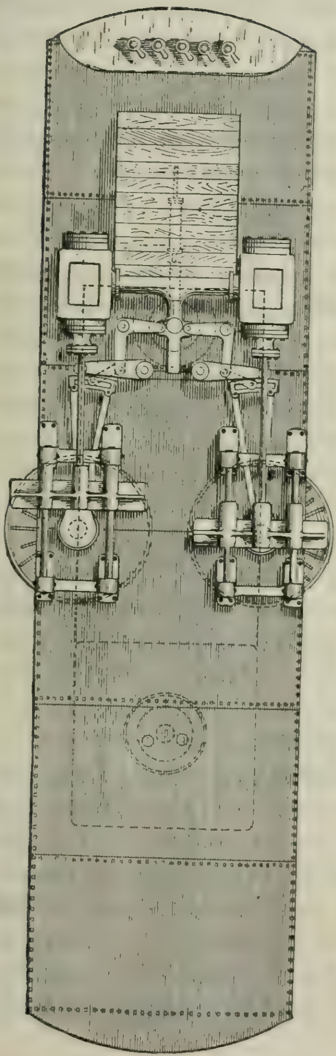


Fig. 60. Scale 3/8" = 1'

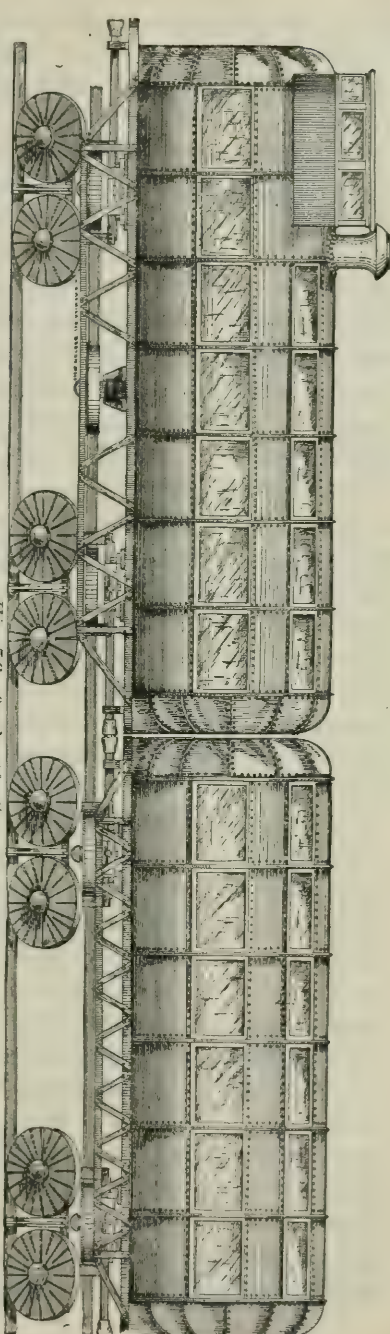


Fig. 58. Scale 1/8" = 1'

end. The crank-pins rotate in square blocks which slide in a rectangular groove in the under side of the cross-heads, the arrangement being in effect the well-known device called the slotted yoke connection.

The slide valves of the usual locomotive form, in steam chests upon the cylinders, are operated by the common link and double eccentrics which are here put upon the driving axles immediately above the floor of the engine, the weight of axles and wheels being supported upon a collar beneath. The only novelty in the valve motion consists in the horizontal instead of vertical position of the links, this requiring somewhat heavier and larger rock-shafts than usual, having vertical axes, the upper horizontal arm of the rock-shaft being connected with the valve rod by means of a short swinging link, and the lower arm carrying the pin within the link block.

For operating the links two bell-cranks shown in the plan are employed, the longitudinal arms of which are connected with the usual link-hanger and strap, though in horizontal position, and the transverse arms with a central sliding piece of wrought iron, which in turn connects with the plunger of a hydraulic cylinder, some 2 inches in diameter by 15 inches long. The throttle valve, link rod, brake and coupling rods, as well as the connection between the driving-boxes for producing pressure and adhesion upon the rails, are all operated by hydraulic power, though hand levers are also retained.

The method of obtaining adhesion of the driving-wheels to the rails, by means of a cylinder and piston attached by pins and eyes respectively to the sliding driving-boxes, which is thus secured independently of the actual weight of the engine, enables it to be made considerably lighter than the ordinary locomotive for the development of the same amount of power. It also attains another very important object, that of a variable adhesion.

The extent of pressure is entirely controlled by a simple three-way hydraulic cock admitting the working fluid, preferably glycerine, under pressure, to the pipes connecting with the cylinder from a receiver or reservoir similar to the Westinghouse air-pressure drum. A hydraulic pump maintains automatically a fixed pressure in this reservoir, or by means of an accumulator ingeniously constructed two grades of pressure per square inch may be automatically maintained, one for operating the pressure

between the driving-wheels, and the other, lesser in amount, for all the other purposes connected with the operation of the engine. The object of the sliding-boxes carrying the driving-wheels is to enable the latter to follow the arc produced by the rails upon curves, and its extent of transverse sliding from a straight line connecting the two trucks is about six inches.

The engine driver occupies the front portion of the engine, the fireman attending to the furnace at the rear end. The former stands or sits upon an elevated platform, and has an unobstructed view of the way through the windows of the monitor roof. Before him upon a shelf are the five hydraulic cocks controlling, respectively, (1) the throttle; (2) the reversing apparatus for the links; (3) the adhesion of the driving-wheels; (4) the brake; and (5) the coupling rods of the entire train, while just above are steam and hydraulic pressure gauges and indicators, speaking tubes to fireman and conductor, whistle and bell ropes, comprising those adjuncts which secure safety and convenience in practical operation.

With an engine having these provisions for a grip upon the rails, any grades from a horizontal to a vertical can be climbed, it being a mere question of supplying sufficient lifting power by the engine.

While no provision has yet been made for connecting the two engines with their driving-wheels together, it being left for practical running to determine the matter, several appliances are in readiness to be added if necessary. This can be accomplished by a mechanical connection in the mechanism, or by the valve motion controlling the steam distribution, or by the independent means of a hydraulic cylinder or auxiliary steam engine to throw either driving-wheel over the dead-points, when needful.

VIII. THE COUPLINGS.

These are automatic in their action, interlocking when coupled, the nose of one draw-bar entering a socket upon the other to form a rigid bar between the two truck centres. A rod extending through them parallel to the draw-bars, and making butt joints when two draw-bars are coupled, controls the coupling hooks, which are similar to the Miller hooks, by means of slotted links of variable throw, and these hooks are operated in such a manner by moving the rods hydraulically that the engineman can uncouple any car in the train, from the engine. The object of this is that

in case of an impending rear or head collision, which are almost the only serious possibilities of accident existing in this system, the engineman, by one movement of the hydraulic cock controlling the couplings, can divide the train into segments consisting of separate cars, each having a brake which sets automatically upon detachment from the train, and thus, by partially destroying the momentum of the whole, cause the collision to take place by a succession of comparatively small blows from the engine and slowing section of the train, instead of by a single blow having behind it the momentum of the entire train. This is accomplished by a hydraulic cylinder and piston upon the tender; the piston-rod of which cylinder pushes upon the coupling rods, compressing springs upon them during traction, and which when pressure is relieved as by movement of the controlling cock or breaking apart of the cars from any cause, causes the rods to spring out, withdrawing the hooks and uncoupling the cars.

Since the cars can neither lift nor swerve from the track by this construction of the coupling and of the trucks, end strains can only be brought upon the car platforms directly in line with them, strength to resist which is the leading feature of their construction.

The draw-bars and couplings have special devices for a continuous and positive connection throughout the train, although allowing the draw-bars to swing upon the truck centres, and contain new features of construction.

IX. THE BRAKES.

The purpose of a brake is to consume the power, momentum or energy of a moving body, such as a train of cars, by creating friction upon the wheels or rails, and it is in this system intended to be operated upon the horizontal or balancing wheels of the trucks, although they may be fitted upon the supporting wheels also. In the former case, they may be automatically operated by powerful springs acting upon toggle-joints so as to cause the wheels to pinch the upper track-beam of the girder, or by shoes upon their rims, controlled in either case by hydraulic means similar to those of the couplings. It is considered preferable to employ spring pressure to throw the action of the brakes on, and positive pressure by the hydraulic cylinder, to throw the friction off, during draft of the train.

It has been found in the Westinghouse brake experiments that the most efficient action of the brakes exists at the point of greatest pressure upon them before slipping of the wheel takes place. If the wheels slip, the friction is at once greatly reduced. That is, more power can be consumed by braking upon the rolling wheels than by the sliding of the same wheels without turning, upon the rails. It is well-known also that in the ordinary form of brake the pressure comes upon but one-half of the longitudinal cross-section of the axle or one-fourth of the brass, owing to the use of half boxes, and the position of the brake block with reference to them.

In this method it is resisted by the full half section of axles, which are made large for the purpose, and the momentum of the train is consumed not only by the friction at the brake-shoe, but upon the axles and rims of the wheels pressing upon the rails, *which latter is doubled, with the same braking force*, by the equal friction produced upon the opposite wheel on the other side of the girder.

The action of the brakes as well as that of traction can be best illustrated by the rails rolling between the rolls of a rolling mill. It is this well-known action reversed, and it is easily seen why no slipping of the wheels can occur by any pressure upon them. Indeed, as in the case of the transmission of pressure through the supporting wheels of the truck directly through the centre of the wheels, which has been discussed, the greater the pressure or load the more these actions are insured.

It should be said that the brakes just described are additional to the ordinary hand-brakes with which each car is to be supplied for use in an extraordinary emergency.

Continuing the discussion of the principal details of this system which have been described, there remains room for the short examination of a few leading points only.

The weights of engine and cars as actually under construction will be about as follows:

			Pounds.
Weight of each truck, complete,			6,400
" engine carriage, exclusive of boiler and engine,			20,336
" engine mechanism,			11,075
" boiler, empty, about,	6,500 lbs.	In ordinary working condition,	8,500
" engine, with boiler, complete,	38,000 "	In ordinary working condition,	40,000

			Pounds.
Weight of tender, complete, .	22,925 lbs.	In ordinary working condition, .	*42,000
" car, ...	25,000 "	Loaded, . .	32,000

There being the same number of supporting wheels for the weight as in the ordinary system, or eight for each engine or car there will be:

	Pounds.
Load per supporting truck wheel on engine, with ordinary working load,	5,000
" " " " tender, " " " "	5,250
" " " " car, " " " "	4,000

Centre of Gravity.—The centre of gravity is considerably lower and the stability greater in this form of railway than in either the New York elevated or in the surface roads. It lies within a few inches of the floor of the car, when loaded, or about twenty inches from the way and rails, while in the other systems named it is nearly four feet above the rails. The principal feature in this construction of way is the low point of support for the load, in connection with a high-placed abutment for draft and brake power.

Curves and Centrifugal Forces.—Upon curves, the way is found to be even stronger in form than upon the tangents, since the action of centrifugal forces at these points has been found to act upon the line of tangent posts, while the hoop form of the girder, so long as it is preserved intact, effectually prevents any concentration of stress upon any single post tending to overturn it. To avoid all locating of posts in the streets, which is always desirable, in turning from one street into another, diagonal trusses may be thrown across from the opposite corner of the street, and the track girders supported upon them, giving all required intermediate support.

Tractive Force and Resistances.—The actual tractive power which it will be necessary to employ in the Meigs system can be determined only by experiment. The resistance to movement of an ordinary freight car on a straight and level road at ten miles per hour is about eight pounds per ton weight, and the total may be divided into a constant resistance due partly to the internal resistances of the friction of the axles, and partly to the external resistances of the rolling friction of the wheels upon the rails; and vari-

* With 1,800 gallons water, weighing 15,000 pounds, and 4,000 pounds of coal.

able resistances. The latter include additional resistances caused by flange friction upon curves and by gravity on ascending grades, the friction of the engine and its machinery, the resistance of the atmosphere and of wind, and those caused by the lateral play of the wheels and transverse oscillations of the engine and train; and all these are affected by the condition of the engine and of the permanent way, the evenness of the track, curves and grades, the weather and wind. They are principally caused, however, by the speed, and increase as the square of the speed. The fact, ascertained by D. K. Clark, that the resistance of a train at sixty miles per hour was twenty-one pounds per ton, forms the basis of a formula deduced by Mr. Forney. Taking the constant resistance at six pounds per ton, since the resistance at any speed to that at a known speed, $R : R^1 = v^2 : v_1^2$, we have the resistance

$$R = \frac{R^1}{v_1^2} \cdot v^2 = \frac{21}{v_1^2}\, v^2 = 6 + \frac{v^2}{171}.$$

The resistances of the atmosphere also vary as the square of the speed, and according to the estimate of Mr. Zerah Colburn, in *Locomotive Engineering*, increase the above one-half, or fifty per cent. The ordinary resistance of curves is stated to be fully covered by a grade allowance of two and one-half feet per mile per degree.*

The total train resistances then, were this railway upon the ordinary system, may be taken at from sixteen to twenty pounds per ton weight of train, at moderate speeds. This would be, for engine, tender, and four cars, weighing in all 210 tons, from 3,360 to 4,200 pounds, exclusive of atmospheric resistances which would increase it to about 6,300 pounds.

The tractive power, or force exerted to move the engine with its train one foot is

$$T = \frac{2\, p\, A \,.\, 2\, S}{2\, \pi\, R},$$

(p, being the mean effective pressure of steam per square inch of piston; A, the piston area, and S and R the stroke of crank and radius of driving-wheel, respectively); or, the tractive force which must be exerted in order to equal and overcome the above resistance for a constant speed of train may be found conveniently by

* H. Haupt, C. E.

multiplying the tractive power *per pound of effective pressure per square inch on the pistons* by the pressure per square inch of the steam upon the pistons. The first is obtained by means of the following formula reduced from that above, or

$$t = \frac{d^2 \times S}{D} = \frac{(12)^2 \times 22 \text{ in.}}{44{\cdot}6} = 71 \text{ lbs.}$$

(d and D being the diameters in inches of piston and driving-wheel respectively). The mean effective pressure exerted through the stroke, assuming the boiler pressure at 150 pounds per square inch, diminished to 130 pounds initial pressure in the cylinders, with the cut-off at one-third the stroke as usual, may be estimated at not far from 100 pounds per square inch of piston area; which, multiplied by the tractive power per pound, seventy-one, gives 7,100 pounds as the maximum constant force exerted by the engine at the rail, to pull the train.

Now the friction of the driving-wheels upon the rail, or the adhesion produced, which alone makes the exertion of the tractive force useful in moving the train, is in the ordinary system entirely dependent upon the weight or load upon the driving-wheels, and is but about one-fifth of this load in amount, on an average. Thus it appears that fully to utilize the power exerted in the cylinders of the engine, there would be required in the ordinary system a load upon the driving-wheels, or a weight of engine upon them of 35,500 pounds, in order to produce the adhesion of the wheels necessary to prevent their slipping. It is estimated that the actual loss by slippage of the wheels and absence of means to prevent the bouncing or jumping of the wheels from the rails upon railroads is not less than one-fifth their circumference in every revolution, causing a constant loss of power to an extent of twenty per cent. of the entire power of the engine. The area of actual contact of these wheels upon the rails has been found by measurement to be surprisingly small, an average of many experiments giving an extent of but $1\frac{1}{4}$ inches traversely to the rail by $\frac{1}{4}$ inch longitudinally—an area varying from $\frac{13}{100}$ to $\frac{42}{100}$ of a square inch, and averaging but $\frac{31}{100}$ square inch; from which it follows that the concentration of pressure upon these limited surfaces varies from 26,607 pounds to 85,961 pounds to the square inch, these enormous forces causing great wear and tear on the rails. It has been

stated by R. Price Williams, an authority upon the maintenance of way in England, that anything which will reduce the resistance due to deflection of track under these forces and consequent abrasion, by one-fifth or one-sixth, will soon effect the saving of the whole cost of the rail.

In the Meigs' system the bearings of the wheels upon the rails are increased about five and one-half times beyond those in existing railroads, while all bouncing from the track is effectually prevented, or at least its evil effects offset, so far as adhesion is concerned, by a corresponding pressure upon the opposite wheel, at the moment of occurrence. There can be no slipping of the wheels, when sufficient power is supplied, in a variable adhesion system; they will always roll, under light or heavy loads equally.

Now an ordinary locomotive having 35,500 pounds load upon the driving-wheels, to make available the 7,100 pounds tractive force we have assumed to be required in this engine, would have to weigh in all at least 60,000 pounds, or thirty tons, whereas this engine exerting the same power will need to weigh but twenty tons, a clear saving in dead weight to be transported, of ten tons, or thirty-three per cent. of the weight of the ordinary locomotive.

The importance of this saving, resulting from the use of means for producing a variable adhesion independent of the weight of engine and possible only upon the system of way adopted, or a similar one, demands particular notice.

Speed.—By this saving in power, an increase can be made in the size of the driving-wheels, to draw a train of equal size as now run, without a material increase in the expenditure of steam and coal; from which it results that with the same number of revolutions of the driving-wheels as that now secured, a large increase in speed is attainable, with the same power of engine. Thus, for example, a ten-foot driving wheel, without slip, would require but 168 revolutions per minute to make sixty miles per hour, while the ordinary five-foot driving-wheel requires to be driven at 336 revolutions per minute, even without slip, to run at sixty miles per hour, which it will be seen is nearly the practicable limit, producing a piston speed of from 1,200 to 1,400 feet per minute. Any large increase of speed beyond this amount can hardly be looked for upon the ordinary railroad, for the requirements of safety against derailment, and the safe working speed of the mechanism, together

with the exertion of sufficient power to move the load, are the limiting conditions which forbid the increase in size of driving-wheels against the rapidly and enormously increasing train and air resistances.

So that, it requiring but 280 revolutions a minute at usual speed of a ten-foot driving-wheel, to make 100 miles an hour, as compared with 336 revolutions with the ordinary five foot driving-wheel to make sixty miles an hour, it will be seen that an ample margin of steam is obtained, together with the absence of slip, to run at such speeds with equal or ordinary power. Thus it becomes perfectly possible and within the capacity of the present locomotive boiler and without increase of piston speed, to run trains at great speed upon the plan proposed, and the inventor confidently predicts regular working speeds of from seventy-five to 100 miles per hour upon this railway with equal and probably greater safety than that with which forty miles an hour are now run. The entire absence of connecting and parallel rods in this engine should be noted as an important point in the attainment of speed with safety from breakage in the engine mechanism.

Power.—Of course the power developed by the engine will vary with the number of revolutions made. Although the term, horse-power, is applicable to stationary rather than to locomotive engines, since as a general distinction the office of the latter is to draw a load rather than to lift a weight through a certain height, its power can be reduced to an equivalent horse-power, this being equal to the product of a certain weight attached by a rope to the circumference of one of the driving-wheels into a certain height through which it is lifted per minute, divided by 33,000. Since the power exerted is equal to the gross work performed, it may be represented, calculated from the effective steam pressure and the speed, as follows:

$$HP = \frac{p \times 2 \times A \times 2 \times S \times N}{33{,}000} = \frac{4\,p\,A\,S\,N}{33{,}000},$$

depending therefore upon the effective pressure, p, per square inch exerted through the whole stroke; the joint area, $2\,A$, of the two pistons; the length of stroke, S, in feet: and the number of revolutions, N, per minute. At sixty miles per hour with ten-foot driving-wheels, the foot-pounds of energy developed at 168 revolutions would be 13,921,606 per minute, and the nominal horse-

power, 422. At 100 miles per hour and 280 revolutions per minute the number developed would be 23,202,676 foot-pounds per minute, and the corresponding number of horse-power would be 703.

As to the train resistances at these speeds it can only be said that no data now obtained are applicable. Their actual extent is simply a subject for conjecture, and can be determined only by actual experiment.

It is evident that the same proportionate advantages may be realized with the adoption of electricity instead of steam as the motive-power, for which the system is especially well adapted, and which it is ultimately the intention to employ, with a consequent avoidance of dust and noise.

In conclusion, and in review there may be noted the following brief statement of advantageous points for the accomplishment of rapid transit, as indicated by this system.

Summary of the Chief Distinguishing Points of the Meigs Elevated Railway System for Rapid Transit.

(1.) Security from derailment by the construction of truck overhanging the girder and tied by the wheel-flanges to the rails.

(2.) The connection of the draw-bars and couplings to the trucks directly beneath the car platforms, preventing telescoping or rising of the cars in case of collision.

(3.) The increased security of the attachment of the car body to the truck, having four posts for each truck, in place of the usual single pivot-pin, and the tying of both together by interlocking flanges.

(4.) Obstruction in the streets and interference to light and view reduced to a minimum, due to the reduction in the width of the permanent way.

(5.) The advantage in strength of way due to bringing the stresses of the load directly over the central line of posts, by means of the diagonal supporting wheels.

(6.) The lowering of the centre of gravity and consequent increase in stability both of the cars and way, as compared with the New York system.

(7.) The advantage of independently rotating wheels for the prevention of slipping and flange friction, enabling each wheel to follow the rail more closely than in the ordinary truck, and thus greatly diminishing its resistance upon curves.

(8.) The increase in breadth of tread of the wheels upon the rails to prevent the concentration of the load upon small areas, and to thus reduce the wear upon the rails.

(9.) The saving of power attained in the production of pressure upon the driving-wheels by means independent of the weight of engine, and controlling the same so as to produce the variable adhesion required.

(10.) The lessening in cost of operation by the reduction in weight of engine and cars.

(11.) The cylindrical form of car and engine, for the diminution of air and wind resistances upon their sides and resulting strain upon the trucks and way.

(12.) The facility of turning sharp curves as small as those of fifty feet radius, enabling it to be constructed in narrow streets, not possible in the ordinary system, and the absence of increased friction and resistance upon the curves.

(13.) The facility and economy in climbing heavy grades without loss of power by slippage, and, in general, by the holding of the wheels against the rail without the possibility of rebounding from them, as in the ordinary system.

(14.) The superior advantage of the system proposed of brakes upon the upper or gripping rails.

(15.) The automatic coupling apparatus for diminishing the danger in head or rear collisions.

(16.) The increased safety of the switch due to its size and construction

(17.) The freedom of the way from obstructions, or from snow and ice lodging upon the way and blocking it.

(18.) The entire absence of grade crossings, of trespasses, or the possibility of other trains crossing at grade.

(19) The economy of construction and maintenance of way due to absence of surface grading, of embankments and drainage ditches, and diminished repairs in alignment, and the cost of the renewal of cross-ties.

(20.) The increased speed made practicable, with safety and economy, due to its special features as a system, as compared with the ordinary system now in use.

(*To be Continued.*)

PHOTOGRAPHY BY A LIGHTNING FLASH.

BY PROFESSOR EDWIN J. HOUSTON.

[*Abstract of Remarks made at the Stated Meeting held November 18, 1885.*]

Mr. Albert S. Barker, of Philadelphia, has recently succeeded in taking two very fair photographic negatives of outside objects while illumined by no other light than that of a single lightning flash. These photographic views were taken at 7 P. M. on Thursday, October 29, 1885, near Philadelphia. The night was excessively dark, the wind strong, and the rain heavy. The camera was placed in an open window, with the slide drawn. The lightning flash came in less than one minute, when the slide was returned. The plate holder was then reversed and suitably placed for a second exposure. The plate was one of the highly sensitive gelatine films.

Mr. Barker developed the plates the same evening. From their behavior he rated the actinic effect of the light as equal to that obtained from an exposure of about $\frac{1}{300}$ part of a second in bright sunlight.

The popular impression as to the duration of the lightning flash is that it is practically instantaneous. From the experiments of Wheatstone and others with the rotating disc, the duration of the flashes measured, would vary apparently from the $\frac{1}{1000}$ to the $\frac{1}{10000}$ of a second. Others estimate the duration of the flash as even shorter than these figures.

It is very doubtful if the average severe flash in this latitude does not endure or continue for a very much longer period. Despite the popular belief to the contrary, the author has frequently observed the motion of foliage when illumined by no other light than the lightning flash. This would not, of course, be the case if the flash were even approximately instantaneous.

It is a very significant fact that in the photographs of Mr. Barker the foliage shows unmistakable evidence of having perceptibly moved during the period of exposure ; thus showing that it was by no means instantaneous.

It is to be hoped that Mr. Barker, or some other photographer, will repeat these exposures under the following conditions, viz., to make the exposure while the camera is sharply focussed on

moving foliage, or a rapidly rotating wheel, while illumined by a lightning flash, so as to determine more definitely the duration of the flash.

In the case of the lightning flash, the large percentage of blue rays would of course render the plate more sensitive to the extremely short exposure by practically prolonging the same, since the ordinary photographic chemicals now employed are especially sensitive to the blue portions of the spectrum.

It would appear from the facts developed by the photographs, of Mr. Barker that the method of measuring the duration of the lightning flash as adopted by Wheatstone and others, which consist essentially in endeavoring to detect by the unassisted eye the change in position of a rapidly moving wheel, or other object, while illumined by the flash, might be greatly improved by substituting for the eye, the sensitive photographic plate since the latter is apparently far more sensitive than the eye.

Should photographic pictures of a rapidly rotating wheel, whose rate of motion was known, be taken while illumined by a lightning flash, the displacement of the image on the negative would give far more reliable data for calculating the duration of the flash than the methods heretofore employed.

Mr. Barker's photographs, therefore, are not only interesting as showing how extremely sensitive the photographic plate may be made, but are also of interest as throwing some light on the possible duration of the lightning flash.

CENTRAL HIGH SCHOOL,
Philadelphia, November 18, 1885.

ORIGIN OF DIASTASE.—Emile Laurent has investigated the question whether diastase is a product of bacterial action, or whether it can be formed without organic intervention. He placed seeds of lupin, maize, barley and helianthus to germinate under a bell-glass, over water which had been previously boiled, the seeds having been first freed from superficial micro-organisms by the ordinary processes of sterilization. When the sprout began to show, the seeds were introduced, with all necessary precautions, into tubes containing Koch's nutritive gelatine. The seeds continued to develop normally, without liquefying the gelatine, which constitutes, according to Koch, an infallible criterion of the absence of bacteria. Sprouted seeds, introduced into sterilized plum juice, continued to grow, without showing any bacteria in the liquid. Although these experiments can hardly be considered as decisive, they lend great probability to Laurent's opinion that bacterial intervention is not necessary—*Bul. de l'Acad. Roy. de Belg., No. 7, 1885.*

CONTACT-MAKER FOR ELECTRIC CLOCKS.

By Louis H. Spellier.

It is well known that the seemingly easiest of all operations in time telegraphy has proved to be its weakest point, and its most obstinate obstacle to attain the perfection desirable for a universal adoption.

It is the contact maker for the electric circuit which has, in many instances, caused the condemnation of secondary electric clocks, the skilful execution and superior construction of which should have entitled them to more deserving consideration.

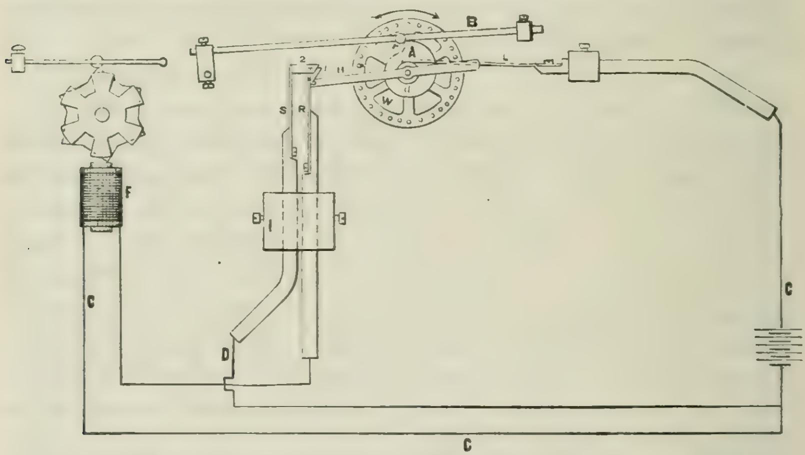
The obstacles that make the transmission of the electrical energy to the secondary electric dials difficult and uncertain, are mainly the effect of the spark resulting from the induced current at the contact terminals of the contact-maker, and the mode of operating the contact-maker by the main clock, without overtaxing its delicate mechanism with more power than is necessary for executing its ordinary functions.

My arrangement to obviate the difficulty arising from the sparks was first published in this journal in March, 1883. For the convenience of those who have not read that article, I will here again explain the manner by which this is accomplished, so that the reader may understand that portion of the accompanying figure, which is intended to avoid the formation of the spark without referring to the number of this journal cited. Although the general arrangement in the illustration of the article named is substantially the same as that of the accompanying figure, the latter shows it in a form especially arranged for electric time service, in combination with that contrivance which, to explain, is mainly the object of this article.

Referring to the figure, E is the electro-magnet of an electric clock; H is a metallic arm designed to produce the closings and breakings of the current. One of the poles of the battery is connected by the wire C with the spring L, which rubs constantly upon the metallic disc d. The latter is fastened on the shaft of the escapement wheel W. The other pole of the battery comes from the electro-magnet E, and is connected with a second spring

R, the projection *1*, of which, comes in contact with a metallic pin at the terminal of the arm *H*. When this contact is made, the current is closed, and *E* can attract its armature. What is now necessary is to avoid the spark produced by the extra current, as soon as the contact between the pin and *R* is broken, since it will occasion a defective contact of the current-breaker. For this purpose, another spring *S*, the terminal of which is also provided with an inclined projection 2, is placed a little above *R*, and is connected by the wire *D* with the returning conductor. Both springs *R* and *S* are insulated from each other, and the clock movement by its bearing *I*.

After the pin has been in contact for a short time with the projection of the spring *R* only, it comes in contact with the projection of the spring *S* also. At this moment, the current passes through the short circuit *S D*. Since both springs are now for a moment in contact with the pin of the arm *H*, the extra current excited in the electro-magnet at the instant the short circuit is made by *S D*, takes its way through *C*, *D*, *S*, *R*, *E*



As stated, my main object is to describe in this article an improved method to operate the contact-maker by an ordinary regulator, which now may occupy our attention. Heretofore, the escapement wheel of any clock, when used for the making and breaking of an electric circuit, to actuate secondary electric clocks, did not exercise any more power at the moment the making and breaking of the circuit occurred, than it did while serving its real purpose, namely, to give to the oscillating pendulum of the clock

the impulses needed for the continuation of its movements. The power necessary for this purpose is very slight, and not energetic enough to make a reliable contact for the passage of the electric current. But since such a contact must be a firm one to make it secure, a frequent failure of forming a complete electric circuit may be a not uncommon occurrence. That this is a circumstance which will greatly interfere with the reliability of secondary electric clocks, needs no further demonstration.

Two methods, to avoid this evil, have been resorted to. One is the use of a relay. In that instance, the escapement wheel of the standard clock makes a very faint contact, sufficient for the passage of a weak electric current, to operate a relay. The relay then closes the main battery of a sufficiently strong current to actuate the electric dials in the circuit.

The other method, which was first executed by Paul Garnier, and which seems to have found at present, the greatest consideration, in Europe, is based upon the use of an extra clock-work, which is set in action and arrested again at fixed intervals by the escapement wheel of the standard clock. This extra clock-work operates the contact-maker of the electric circuit for the secondary dials, and is provided with ample power to effect a secure and firm contact.

If properly constructed and executed, this method has proved to be a very reliable one. Its main objection rests in the fact, that it is rather complicated in construction, and too costly to be purchased where but a few electric dials are desired, and, above all, an attendant of but little skill cannot be entrusted with the maintainance or repair of such an arrangement. This is a fact which may justly receive full consideration in many places, where an experienced mechanician is not at hand. To meet this emergency is the object of the device shown in the diagram. It is intended to enable us to use in a simple and yet effective manner the escapement wheel, or its shaft, of the standard clock directly for the making of a firm electrical contact. But since, as stated, under ordinary circumstances the escapement wheel has not sufficient force to accomplish this work, I have endeavored to invent a mechanism by which the escapement wheel, during the time the electric contact is made, receives an additional amount of power for the operation of the contact-maker.

Its action will be readily understood.

The escapement wheel W moves in the direction of the arrow. Besides the contact arm H its shaft carries, also rigidly fastened to it, the cam A. The pin of the arm H is now in contact with the projection of the spring S, for the purpose of completing the electric circuit. At this time an increase of the power exercised by the escapement wheel is needed, to overcome the obstruction offered by the tension of the contact springs. To arrive at this result is the purpose of the cam A, and the weighted lever B, which is pressing against the curve of the cam by a little roller r. It will be observed, that just now the roller of the lever presses against the incline i of the cam. Thereby it imparts additional power to the shaft of the escapement wheel by its pressure, and assists to overcome the obstruction offered by the contact springs. The moment the contact pin has passed the projections of both contact springs, the roller r of the weighted lever reaches the lower part of the cam. It is gradually raised again as the escapement wheel revolves, and will repeat the same operation at the next contact between the pin of the contact arm and the projections of the springs. It is hardly necessary to mention, that the whole mode of operation is but a gradual storing up of a portion of the power expended by the escapement wheel during the course of its revolution, which is returned to the same at the proper moment for the purpose demonstrated.

It is obvious that the relative conditions between the weight of the lever L and the tension of the contact springs can be easily so adjusted that when the shaft of the escapement wheel is impelled with increased force this increase is exactly absorbed by the tension of the contact springs, leaving for the functions of the escapement wheel only so much force as properly belongs to it.

All regulators that were provided with this contact-maker needed but a slight additional weight (in some instances even this was not needed). In no case were the time-keeping qualities affected to any perceptible degree.

In conclusion, I may mention, that the diagram also shows the three principal features of my system of time telegraphy systematically connected.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS OF THE FRANKLIN INSTITUTE ON GREENE'S PROCESS OF EXTRACTING OIL AND ALBUMINOID MATTER FROM CORN, ETC.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 10, 1885.

The Committee of the Chemical Section as a sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to which was referred for examination:

"THE PROCESS OF EXTRACTING OIL AND ALBUMINOID MATTER FROM CORN." BY DR. F. V. GREENE, OF PHILADELPHIA,

report that the invention has for its aim the separation of fatty and nitrogenous matter as a by-product from the liquors of starch factories, from which the starch has been deposited.

In the manufacture of starch, corn is steeped in water, and kept at a temperature favorable to promote fermentation and putrefaction, for the purpose of loosening the cellular tissue, and to liberate the starch granules as well as possible. In order to accelerate this process, an addition of a small quantity of alkali, preferably caustic soda, is generally made, while other manufacturers, for the dissolution of the inter-cellular matter, prefer the use of dilute acids, especially sulphurous acid

After twenty-four (24) to forty (40) hours standing, the steeped corn is reduced to a pulp by grinding, from which the starch is then obtained by brushing through sieves and an elaborate process of floating and settling. In the spent liquors, remain dissolved, the soluble parts of corn, such as sugar, gum, albuminoid substances, gluten, salts, etc., which hold in emulsion fatty and resinous matter, and also suspended cellular and other insoluble matter.

It is this milky liquid to which the inventor applies his process. The liquors are mixed with a small quantity of a solution of sulphate of alumina, which renders insoluble the albuminous substances (for the larger part). These in coagulating, envelop and precipitate the fatty matter, as well as the coarser particles, so that the liquor, after settling, is left almost clear. The precipitate is separated by subsidence or filtration, and pressing, and after proper drying, forms a grayish coarse powder, the by-product of starch

factories, as intended by the inventor. The same treatment is also proposed for the residues of distilleries and vinegar factories.

From the dry product, the oil may be obtained by pressure, or by extraction with benzene or bi-sulphide of carbon, and the exhausted residue is proposed as fertilizer for the sake of its nitrogenous matter. Mr. Trimble found 4·26 per cent. nitrogen in a sample; whilst Mr. Haines found 4·75 per cent. in another sample of this exhausted residue, which amount the inventor expects to increase to eight per cent. by improved operations. The quantity of oil obtained is reported by the inventor as being about one-tenth of the dry precipitate.

As far as your committee could judge, the oil, which in its crude state is dark-colored, has a good body, and is capable of bleaching. After all odor of the remaining extracting medium (hydro-carbons or bi-sulphide of carbon) is dissipated, the oil has a very agreeable flavor of its own. Undoubtedly, it would make a very satisfactory soap-stock.

Your committee had no chance to see the process carried out on a manufacturing scale, and no facilities to operate with larger samples, yet they are under the impression that it should work to satisfaction under otherwise favorable circumstances.

The drying of the precipitate, which, in its nature, must be very bulky and pasty, will undoubtedly be somewhat difficult and expensive; considering, however, that the waste waters will by this treatment at the same time be disinfected, the process would be a great boon to the whole community in removing a public nuisance—putrefying waste waters of starch factories. Its introduction should, therefore, be encouraged, even if it should fail to pay large profits as an enterprise of its own.

(Signed) OTTO LUTHY.
J. W. EASTWICK.
January 6, 1885. H. W. JAYNE.

Amended to incorporate the recommendation of the award of the "John Scott Legacy Medal and Premium."

Adopted as amended January 6, 1886.

(Signed) H. R. HEYL, *Chairman.*

I hereby certify that the above is a correct copy from the record.

[SEAL] (Signed) WM. H. WAHL, *Secretary.*

Franklin Institute.

[*Proceedings of the Annual Meeting, held Wednesday, February 17, 1886.*]

HALL OF THE INSTITUTE, February 17, 1886.

COL. CHAS. H. BANES, President, in the Chair.

There were present 120 members and twelve visitors.

Five new members were reported as having been elected at the last meeting of the Board of Managers.

The President delivered an inaugural address in which, after paying a warm tribute to the ability and devotion with which his predecessor—MR. TATHAM—had discharged the duties of President, he spoke at length of the "Influence of the FRANKLIN INSTITUTE on the Development of the Mechanic Arts in Philadelphia." Setting forth the capabilities for usefulness which the INSTITUTE should possess, when properly equipped for the work; giving a sketch of its past services; and presenting, forcibly, a plan to our citizens for aid in placing the INSTITUTE in new and enlarged quarters, and with adequate means and facilities for carrying on its work.

The address was ordered to be printed and 5,000 copies thereof in pamphlet form, issued for distribution to members and to the public.

The Secretary's report embraced a résumé of technical progress during the year 1885.

MR. RUDOLPH HERING followed with some remarks on "Steam Traps," illustrated with views, exhibiting faulty and correct constructions.

MR. WM. A. CHEYNEY made some remarks, giving his views respecting the future development of the INSTITUTE.

The President named the following as the Standing Committees of the INSTITUTE, for the current year, viz.:

Library.	*Minerals.*	*Models.*
Charles Bullock,	Clarence S. Bement,	Edward Brown,
J. Howard Gibson,	Persifor Frazer,	H. L. Butler,
Frederick Graff,	F. A. Genth,	C. Chabot,
Wm. D. Marks,	Edwin J. Houston,	L. L. Cheney,
S. H. Needles,	George A. Keonig,	N. H. Edgerton,
Isaac Norris, Jr.	Otto Luthy,	John Goehring,
A. E. Outerbridge, Jr.	E. F. Moody,	Morris L. Orum,
Chas. E. Ronaldson,	H. Pemberton, Jr.,	Chas. J. Shain,
Wm. P. Tatham,	Theo. D. Rand,	John J. Weaver,
Lewis S. Ware.	Wm. H. Wahl.	S. Lloyd Wiegand.

Arts and Manufactures.	*Meteorology.*	*Meetings.*
J. Sellers Bancroft,	John Bullock,	Hugo Bilgram,
George Burnham,	Wm. A. Cheyney,	A. B. Burk,
George V. Cresson,	Charles M. Cresson,	G. M. Eldridge,
Cyrus Chambers, Jr.,	J. A. Kirkpatrick,	Frederick Graff,
Wm. Helme,	G. Burtis Lee,	Wm. H. Greene,

Arts and Manufactures.	*Meteorology.*	*Meetings.*
Wm. B. Levan,	F. B. Maury,	Robt. B. Haines, Jr.,
Alfred Mellor,	Isaac Norris, Jr.,	Henry R. Heyl,
Henry Pemberton,	Hector Orr,	Washington Jones,
Wm. Volmer,	M. B. Snyder,	G. H. Perkins,
John J. Weaver.	Wm. H. Wahl.	E. Alex. Scott.

The following were announced as constituting the Special Committee on new building: WM. P. TATHAM, WM. SELLERS, J. VAUGHAN MERRICK, CHAS. BULLOCK, ISAAC NORRIS, JR., JNO. J. WEAVER, and CHAS. H. BANES.

Adjourned.

WM. H. WAHL, *Secretary.*

At the Annual Meeting, held Wednesday, January 20, 1886, the following reports were presented and accepted:

REPORT OF THE COMMITTEE ON LIBRARY FOR THE YEAR 1885.

WM. P. TATHAM, *President.*

SIR:—The Committee on the Library respectfully report that during the past year there have been added to the Library—

	Bound.	*Unbound.*	*Pamphlets.*	*Maps.*
Books purchased—volumes, . . .	224	34	92	. .
" " from B. H. Moore fund,	93	. . .	. . .	. .
" presented, ...	879	613	2,716	24
" purchased for Memorial Library,	17	1	3	. .
" donated to Memorial Library, .	5	20	17	. .
Exchanges bound, ...	452	. . .	. . .	. .
Books, other than Exchanges bound, .	128	. . .	. . .	. .
" rebound, ...	2	. . .	. . .	. .
	1,800	668	2,828	24

Making a total of	5,296	volumes.
To which are to be added the volumes presented by Mrs. WM. B. ROGERS, from the library of the late Prof. ROBERT E. ROGERS, ...	883	"
And the volumes taken from the pamphlet collection and added to the Library, ...	97	"
Total additions during the year 1885, . .	6,276	volumes.

Making the total number of volumes bound and unbound in the Library 24,240, exclusive of pamphlets, an increase of 8,861 volumes in the past five years.

The large amount of valuable pamphlets which has accumulated demanded an assorting and classifying of them, with an index which would make them available for reference—this work has been in progress during the past year, and 3,299 pamphlets have been so arranged; the work is still in progress.

THE EXCHANGES for the JOURNAL OF THE INSTITUTE number 331.

DUPLICATES.—A printed catalogue has been sent to the prominent Libraries of the United States with the view of effecting an exchange. During the year 114 volumes and pamphlets have been received in exchange.

SERIAL PUBLICATIONS.—A number of important works of this class have been completed, and the committee are endeavoring to fill up the deficiencies in important works

STATE PUBLICATIONS.—With the view of obtaining the official publications of the different States, correspondence has been opened, proposing to exchange the JOURNAL OF THE INSTITUTE for such publications, and favorable responses have been received from a number of States.

The increase of the Library has made it necessary to devise expedients for the relief of its crowded shelves. Many books which are least consulted have been removed to the model room, and shelving has been erected in part of the drawing room to relieve the pressure for space.

A new table for the Librarian, with conveniences for arranging and keeping the card catalogue, has been placed in the library during the past year.

CHAS. BULLOCK,
Chairman of Committee on the Library.

PHILADELPHIA, January 20, 1886.

REPORT OF THE ELECTRICAL SECTION FOR THE YEAR 1885.

WM. P. TATHAM, *President.*

SIR:—I have the honor to report that the Electrical Section of the FRANKLIN INSTITUTE has completed its second year with a considerable increase of membership, and an increase in attendance, which augurs well for the future.

The Treasurer reports, after paying all expenses, a balance in hand, January 15, 1886, of $123.14—not enough to enable us to purchase any instruments, but showing, nevertheless, careful and economical management.

The Secretary reports as follows:

During the past year, ten (10) names have been added to our list of members. We have lost one worthy member in the death of Mr. John W. Nystrom. Our membership at the close of 1884 was thirty-one (31) and, making the corrections to correspond with the above, would bring our *active* list up to forty (40) at the close of 1885. There is one honorary member, who was elected the past year. In addition to these, there are now three names before the Nominating Committee, to be acted upon at our next stated meeting.

Regular stated meetings were held once a month, excepting during July and August. One adjourned meeting was held December 14th, on account of Prof. Dolbear's lecture on "Telephone Systems," occurring on the night of the regular meeting, also one on January 5, 1886.

The average attendance has been 9·9. The largest number present at any one time was sixteen; the least, six. The attendance at the first adjourned meeting was eight; at the second, ten. Several visitors were present from time to time.

Ten (10) special committees were appointed during the year and one continued from the previous year—the Parkhurst Battery Committee.

Of these, five (5) were appointed to investigate subjects referred to the Section from the Committee on Science and the Arts. Three of these made the proper investigation, the reports were accepted by the Section and handed to the Committee on Science and the Arts, and duplicate copies placed on file in the archives. The subjects of these reports were:

Mr. W. B. Cooper's Thermo-magnetic Motor;

Mr. Wm. Walter's System of Underground Conduits;

Mr. Lucius J. Phelps' Induction Telegraph System as Applied to Moving Railway Trains.

Two are still under consideration, namely:

The Parkhurst Battery;

Mr. Van Gestel's Combined Arc and Incandesc[illegible] amp.

Of the other special committees, those appointed to examine—

Mr. Murray Bacon's automatic signaling apparatus between the pilot and engineer of steam vessels; to report upon the advisability of the Section giving a course of lectures; and to

Revise the By-Laws,—presented reports which were accepted and filed.

The Committee on Instruments was made a standing committee, and the committees to—

Review the current electrical journals,—and to

Report on increasing the scope of the Section, have been continued.

There were brought before the meetings, from time to time, for the inspection of the members:

The Edgerton Motor;

Some experimental apparatus, illustrating the principles of the Cooper Thermo-Magnetic Motor;

Model of a section of Walter's Underground Conduit;

Photographs of flashes of lightning;

Photograph showing the separation of the carbons in a telephone transmitter (believed to be the first time on record);

The original seal of the first magnetic telegraph company;

And the Diehl Motor.

Mr. W. W. Griscom read a paper before one of the meetings on the methods of testing the efficiency of motors. The committee appointed to review the electrical journals presented numerous interesting notes from the home and foreign periodicals, and several interesting discussions have taken place at different times.

A very valuable donation was recently presented to the Section by the members of the family of the late Jos. Sailer, consisting of two printed and bound volumes of the minutes and transactions of the first magnetic telegraph company, from the time of its organization, May 15, 1845, down to 1859, when it amalgamated with the American Telegraph Company.

The historic value of this gift can scarcely be estimated, as the records contain a minute and exact account of all the difficulties that had to be overcome before the telegraph reached even the practical working standpoint it had attained twenty-seven years ago. In connection with this, Mr. Joseph Sailer, Jr., very kindly presented the original seal of the company to the Section as a valuable relic of the earlier days of telegraphy. Suitable letters were drawn up and forwarded to the donors, expressing the thanks of the Section for these valued gifts.

In retrospect, the opinion of your Secretary is, that the year just closed was one of marked advance for the Electrical Section, and our present condition warrants the prediction that a bright future is before us in the year just opening.

The Committee on Increasing the Scope of the Electrical Section report as follows:

ELECTRICAL SECTION, FRANKLIN INSTITUTE.

PHILADELPHIA, January 5, 1886.

To the President and Members of the Electrical Section:

Your committee to whom was referred the question of devising means to develop the usefulness of the Section and to secure a more regular attendance of its members, beg leave to make the following report:

The committee have held several meetings, and have discussed the subject in all its bearings. The active membership of the Section is forty-two, but while the average attendance at the meetings is fair, there is too small a proportion of members regularly present to secure the best results.

The first requirement of a successful organization is that there shall be a sufficient number who can be positively relied upon to attend all the meetings and enter heartily into the work of the Section. There is undoubtedly more than enough members willing to form such a nucleus if the meetings can be made sufficiently interesting to draw them together. This is proven by the fact that whenever anything of special interest is announced the attendance is large and the meeting is a profitable one.

What then can be done to improve the character of the meetings? The committee have received many valuable suggestions from the other members, which have been carefully considered; among them, that of bringing before the meetings systematically the latest information culled from American and foreign electrical journals, which has already been acted upon by the Section; that we shall arrange to have lectures from eminent electricians delivered before the Section; and third, that the several members of the Section shall prepare and read at the stated meetings monographs on electrical subjects; all of which are recommended by the committee for favorable action.

This, however, will not meet the case. It has long been recognized that the Section is not properly equipped for doing the work which is expected of it. It is true that it has made several reports, which have been very satisfactory to the INSTITUTE, on important electrical inventions which have come before the INSTITUTE for investigation, but it has been unable to properly investigate many of the subjects which have been referred to it by the Committee on Science and the Arts, because it has had no facilities at its command to make the necessary tests or experiments to prove or disprove the claims of the inventor.

What is needed is a small laboratory, with a comparatively few instruments to start with; and this laboratory and its equipment should be under the exclusive control of the Section. The opportunity which it would afford for original investigation, and for conveniently demonstrating the truth or falsity of newly-advanced theories, etc., would go far to enlist the active coöperation of many members who at present feel this lack of facilities, and who could not otherwise be interested in the work of the Section.

Can the INSTITUTE supply our necessities in this respect, or can individuals be found who will put the Section on its feet? In answer to this, it may be stated that some of the necessary instruments were purchased by the INSTITUTE for the use of the Section just at the close of the Electrical Exhibition, over a year ago. They comprise one Wiedermann galvanometer, one set of Hartmann resistance coils, one telescope and scale for reading the galvanometer, and one standard ohm. These instruments have not yet come into the possession of the Section. They have been doing good work in the hands of the experts employed by the INSTITUTE to conduct the tests on incandescent lamps and on dynamos, the admirable reports of which have been recently published. It is important that the Section should come into possession of these or similar instruments whenever it has a proper place to mount them.

Can the INSTITUTE give us a room for a laboratory? This matter has been carefully looked into. The committee believe that, if possible, this laboratory should be within, or near, the INSTITUTE building and its archives. A suitable room should be upon the ground floor, and it has been suggested that underneath the occupied portions of the building there is a large basement which, many years ago, was divided into rooms and used for drawing schools, etc., but which is now occupied for storage only. Possibly accommodations could be secured in that basement, either in one of the unused rooms on the street, or further back; and it is recommended by the committee that application be made to the Board of Managers not only for suitable quarters for a laboratory, and for the archives of the Section, but also for the custody of the instruments before referred to.

The suggestion has been made that it would be proper and advisable to use the funds in the treasury of the Section for the purchase of instruments, and that we might, perhaps, be able to secure contributions for this purpose. Certain members of the Section have offered to construct some of the necessary instruments, and Professor Anthony, of Cornell University, has kindly agreed to graduate them at a nominal charge.

A nucleus of earnest workers and a little encouragement and aid from the parent organization would soon make the Section a valuable adjunct to the INSTITUTE; there would be plenty of work for it to do and there would be no lack of interest in the work. The times seem to be propitious for the establishing of a good, strong electrical organization in this city, either under the auspices of the INSTITUTE or independent of it. Electrical science is now making rapid growth, and it would seem eminently proper that the INSTITUTE which, in times past, has been prominently identified with that science should not now take a secondary position.

The recommendations of the committee are briefly,—to bring before the meeting recent electrical news; to arrange at the proper time for lectures; to prepare monographs on electrical subjects; and to memorialize the Board of Managers for quarters and instruments.

Respectfully submitted,

E. ALEX. SCOTT, *Chairman*,
JAMES WILSON,
CHAS. H. RICHARDSON,
R. B. HAINES, JR.,
A. B. BURK.

In conclusion, we have to acknowledge the many and important advantages which the FRANKLIN INSTITUTE confers on its Sections, with the hope that it may see fit to grant the Electrical Section the further assistance which its growing usefulness would appear to warrant.

W. W. GRISCOM, *President.*

REPORT OF THE CHEMICAL SECTION FOR THE YEAR 1885.

WM. P. TATHAM, *President.*

SIR:—The Chemical Section of the INSTITUTE respectfully reports that during 1885 the following officers served:

President.—PROF. S. P. SADTLER.

Vice-Presidents.— { DR. ISAAC NORRIS.
MR. G. G. BROWNING.

Treasurer.—MR. CHAS. BULLOCK.

Conservator.—DR. WM. H. WAHL.

Secretary.—HENRY PEMBERTON, JR.

The membership at the end of the year was fifty; four members having been elected, and one having resigned during the year.

The following subjects were brought before the meetings and discussed:

Analyses of water from near Reading, Pa., by Prof. Luthy.

Analyses of Extracts of Licorice, with samples, by Prof. Sadtler.

Beautiful specimens of anthracene, anthraquinone, alizarine, carbon tetrabromide, and phosphorous subsulphide, by Dr. H. W. Jayne.

Manufacture of beet root sugar, with methods of removing foreign bodies, by Prof. Luthy.

The Bower-Barff process of giving iron a non-oxidizable coating, by Prof. Sadtler.

Use of blast furnace slag for paving purposes, and for manufacture of "slag-wool," by Prof. Sadtler.

A new apparatus for accurately determining the volume of gases, invented and described by Dr. Keiser.

Process for extracting oil and albuminoid matter from corn, patented and described by Dr. F. V. Greene. This process was referred by the Committee on Science and the Arts to the Chemical Section, was examined and reported upon by a sub-committee, and transmitted by it to the Committee on Science and the Arts.

In addition to the above, a variety of other matters received an informal and general discussion at different times.

The Section subscribes to a number of foreign chemical journals, which are bound by the INSTITUTE, and kept upon its shelves.

Regular meetings are held on the second Tuesday of each month, except during summer. The members have shown much interest in the meetings, and the attendance has been good; particularly so during the latter half of the year.

Respectfully,

HENRY PEMBERTON, JR., *Secretary.*

PHILADELPHIA, January 12, 1886.

REPORT OF PHONETIC SHORTHAND SECTION FOR THE YEAR 1885.

W. P. TATHAM, *President.*

SIR:—I beg leave to report that the Phonetic Shorthand Section, through its Executive Committee, continued the organization of the practice class of the Section during the first six months of the year. The meetings of this class were held one each week with an attendance of from twelve to twenty pupils. Last spring a very interesting lecture was delivered under the auspices of the Section, by Mr. John Sartain, on "Ancient Art," which was published in the JOURNAL OF THE INSTITUTE.

Since the organization of the Section much has been done through its influence to secure a uniformity in shorthand writing in this city and in simplifying the methods of teaching it. Many of the pupils taught in its classes are filling important clerical positions in some of our largest business houses, and the demand for really good shorthand clerks is now greater than the supply.

The teaching of phonetic shorthand according to the primary method has been introduced into the Northern Home for Friendless Children and the Soldiers' Orphans' Institute, through the influence, direct and indirect, of this Section. The Section was directly instrumental in introducing the teaching of shorthand classes in Girard College, the New Century Guild for Working Women, and the Women's Christian Association.

Shorthand is not yet taught in the Public Schools of Philadelphia, but many teachers in public schools have received instruction in the art in accordance with the resolution of the Committee of Instruction of the FRANKLIN INSTITUTE. Very Respectfully, E. ALEX. SCOTT,

Prest. Phon. Shorthand Section.

PHILADELPHIA, December 16, 1885.

BOOK NOTICE.

SPECIALISTS' SERIES VOL. I. MAGNETO- AND DYNAMO-ELECTRIC MACHINES: with a Description of Electric Accumulators. From the German of Glaser de Cew by F. Krohn, edited by Paget Higgs, LL. D., D. Sc. London: Symons & Co. New York: D. Van Nostrand.

The author presents a well arranged and complete treatise upon the subject indicated in the title. A historical outline of the development of the dynamo-electric generator is followed by a description in detail with numerous illustrations of the various constructions and applications of both alternating and direct current machines, with a comparison of their relative advantages and disadvantages under varying conditions.

One chapter is specially devoted to electrical accumulators.

The theoretical treatment is very complete, including the latest theories advanced by the highest authorities.

The construction of electric generators as well as their application to lighting purposes, etc., receives able treatment, including the latest obtainable data.

Special attention is directed to the description of instruments for electrical measurements. H. B.

LIST OF BOOKS

ADDED TO THE LIBRARY FROM MARCH 1, 1885.

Cambridge, Mass. Annual Report of Board of Health. 1884.
Presented by the Board.

Canada. Annual Report of Minister of Railways and Canals for Fiscal Year ending June 30, 1883. Presented by the Minister.

Canada, Map of Dominion of. 1882.
Presented by the Minister of Railways and Canals.

Canada, Railways of. Maps to Accompany Annual Reports on Railway Statistics. 1884.

Canada, Reports of Railways Statistics of. For 1875–76 and 1877–78 to 1883–84. Ottawa, 1877–85. Presented by the Minister.

Canadian Institute. Proceedings. Vol. 1. Toronto.

Central Railroad and Banking Company of Georgia. Thirty-seventh, Fortieth to Forty-ninth Annual Reports, 1872–84.
Presented by the Company.

Ceylon. The Patent Law, Practice and Forms. New York, 1885.
Presented by Richards & Co.

Chadwick, F. E. Report on the Training Systems for the Navy and Mercantile Marine of England, etc. Washington, 1880.
Presented by Prof J. R. Soley, Library Navy Department, U. S.

Chance, Dr. H. M. Relative Value of Coals to the Consumer. 1885.
Presented by the American Institute of Mining Engineers.

Chase, P. E. Further Experiments in Weather Forecast.

Chemical News. Vols. 49–50. London, 1884.

Chemical Society. Journal. Vols. 43–46. London, 1883–84.

Cherokee Nation, Laws of. Passed during the Years 1839–67. St. Louis, 1868.

Cheshire Railroad Company. Thirty-ninth and Fortieth Annual Reports of the Directors. 1884–85. Presented by the Company.

Chicago Board of Public Works. Third Annual Report for Fiscal Year ending March, 1864. Chicago.

Chicago, Burlington and Quincy Railroad Company. Thirty-first Annual Report of Board of Directors, 1884. Cambridge.
Presented by the Company.

Chicago Historical Society. Early Society in Southern Illinois. By R. W. Patterson, Chicago, 1881; and, Father Marquette, at Mackinaw and Chicago. By H. H. Hurlbut. Chicago, 1878.
Presented by the Society.

Chism, R. E. Mining Code of Mexico. Transactions of American Institute of Mining Engineers. 1885. Presented by the Institute.

Cincinnati. Annual Reports of the Health Department to Councils, 1884.
Presented by C. W. Rowland, Health Officer.

Cincinnati Industrial Exposition. Twelfth Report of the Board of Commissioners. 1884. Cincinnati. Presented by the Secretary.

Cincinnati, Ohio. Annual Reports of Water Department for 1883–84. Presented by the Department.

Cincinnati. Public Library. Bulletins of Books added in 1878–82 and 1884. Cincinnati Finding List. 1882–84. Presented by the Librarian.

Cincinnati Society of Natural History. Journal. No. 1, Vol. 8. Cincinnati, 1885. Presented by the Society.

Cincinnati Southern Railway. Report on the Progress of Work and Cost of Construction. By G. Bouscaren. December 1, 1877. Cincinnati, 1878. Presented by the Author.

Cleveland. Board of Trustees of Water Works. Twenty-seventh to Twenty-ninth Annual Reports to Councils. Presented by the Board.

Coast and Geodetic Survey, United States. Catalogue of Charts for 1884, and Charts Nos. 14, 21, 142, 143, 162a, 175, 186, 195, 208, 209, 359, 359a, 363, 371a, 425, 455a, 455b, 455c, 464b, 464c, 464g, 610, 621a, 643a, 681a, 710, 712, 714, and New York Harbor, also Methods and Results, and Appendix 19, and Report for 1883. Presented by United States Coast and Geodetic Survey.

Collection of Pamphlets from the New Orleans Exhibition. 1884–85. Presented by Messrs. Ware, Wahl and Heyl.

Colorado. Experiments and Public Work of State Agricultural College. 1884. Presented by the College.

Colorado State Business Directory, with Colorado Mining Directory, etc. 1882. Denver, Col. Presented by Charles Bullock.

Columbia College, New York:

Hand-Book of Information. 1878–1880.

School of Arts. Circular of Information. 1883–84; 1885–86.

Rising Generation. An Address by W. A. Duer. 1848.

Historical Sketch. 1754–1876.

Commencement. October, 1850.

Philolexian Society. Constitution and By-Laws. 1860, 1861.

Inaugural Addresses. March, 1848; November, 1849; February, 1858; November, 1858.

Catalogue of Governors, Trustees and Officers, and Alumni and other Graduates. 1754–1882.

Catalogue of the Books and Pamphlets in the Library. 1874.

Annual Registers. 1862–63; 1864–65; 1865–66; 1866–67; 1877–78; 1878–79; 1879–80; 1881–82; 1883–84; 1884–85.

Librarian's Reports for 1862, 1875 and 1884.

Presented by Mr. Melvil Dewey, Chief Librarian Columbia College.

Columbus, Hocking Valley and Toledo Railway Company. First and Second Annual Reports, for 1881–82. Columbus, O. Presented by the Company.

Commerce, Manufactures, etc. Reports from the Consuls of the United States. Nos. 48–50. February, 1885. Washington. Presented by the Department of State.

Commercial Exchange. Twenty-second, Twenty-fifth to Thirtieth Annual Reports. Philadelphia, 1876, 1879–84. See Corn Exchange Association. Presented by the Secretary of the Exchange.

Commercial Relations of the United States. Reports from the Consuls for March, 1885. No. 51. Washington.
Presented by the Secretary of State.

Comptroller of Currency. Annual Reports for 1867, 1871, 1873, 1877–78, 1880–83. Washington, 1868–84. Presented by the Comptroller.

Corliss Steam Engines. Catalogue of Robert Wetherill & Co., Philadelphia. J. B. Lippincott & Co. Presented by Wetherill & Co.

Corn Exchange Association. Second, Third, Fifth to Eighth Annual Reports. Philadelphia, 1856–57, 1859–62. See Commercial Exchange.
Presented by the Association.

Council Bluffs, Iowa. Messages of the Mayor, 1883–84.
Presented by the Mayor.

Courtonne, E. Langue Internationale Nèo–Latine. Nice, 1875–1884.
Presented by the Author.

Courtonne, E. Langue Internationale Nèo–Latine. Nice, 1884.
Presented by the Author.

Croton Aqueduct Department. Annual Reports for 1852, 1856–57, 1861–67. New York, 1853–68.

Dandolo. History and New Methods of Raising Silk Worms. Vol. 1, 1816, and Vol. 2, 1818. Presented by Mr. S. H. Needles.

Danielsonville, Conn. Annual Reports of the Warden, Chief Engineer and Treasurer for Year Ending April 7, 1884–85.
Presented by the Chief Engineer.

Davenport Academy of Natural Sciences. Proceedings. Vol. 2, Part 2, and Vol. 3. 1877–81. Davenport, Iowa. Presented by the Academy.

Davis, Charles Thomas. The Manufacture of Leather. Philadelphia, 1885.
Purchased with B. H. Moore Fund.

Dayton Water Works. Fifteenth Annual Report of the Trustees for the Year ending December 31, 1884. Presented by the Secretary.

Department of Agriculture, U. S. Annual Report for 1884. Washington, 1884. Presented by the Commissioner.

Department of Agriculture, U. S. Bureau of Statistics. New Series. Report No. 16. Washington, 1885. Presented by the Department.

Department of Agriculture, U. S. Bureau of Statistics. Report No. 19. New Series. Washington, 1885.
Presented by the Commissioner of Agriculture.

Department of Agriculture. Chemical Division. Bulletin No. 5. Washington, 1885. Presented by the Commissioner of Agriculture.

Devooght, F. Cable Railroad and Cable Tramways. Antwerp, 1884.
Presented by V. Schaffers, Antwerp.

District of Columbia. Annual Reports of the Board of Health for 1872–76, and Annual Reports of Health Officer for 1879–81. Washington.

District of Columbia. Annual Reports of the Health Officer for 1882–84. Washington. Presented by the Health Officer.

Dominican Republic. Report of the Commission of Inquiry to Santo Domingo. Washington, 1871.

Presented by Professor J. R. Soley, Librarian Navy Department, U. S.

Draper, Henry. On the Use of Carbon Bisulphide in Prisms. 1885.

Presented by the Author.

Electrician. Vols. 1-3. New York, 1882-84.

Électricien, L'. Tomes 7-8. Paris, 1884.

Elektro-Technische Bibliothek. Vols. 19, 22-26. Wien.

Engine, Boiler and Employer's Liability Insurance Company. Chief Engineer's Annual Report for 1884. Manchester.

Presented by the Company.

Engineer. Vol. 57. London, 1884.

Engineer Department, U. S. A. Analytical and Topical Index to the Reports of the Chief of Engineers, 1866-79. Washington, 1881.

Presented by L. Y. Shermerhorn.

Engineer Department, U. S. A. Annual Report of the Chief for 1884. Washington, 1885. 2 Sets.

Presented by the Department and Dr. W. H. Wahl.

Engineer Department, U. S. A. Professional Papers. Nos. 5 and 16 Supplement. Washington. 1850 and 1868. Presented by the Department.

Engineering. Vol. 37. London, 1884.

English Mechanic. Vol. 38. London, 1884.

Erie, Pa. Annual Report of the Board of Water Commissioners for 1884.

Presented by the Board.

Espy, J. P. The Human Will. Cincinnati, 1860.

Explorations and Surveys, Reports of, for the Location of Interoceanic Ship-Canals through Isthmus of Panama, and by the Valley of the River Napipi, by U. S. Expeditions. 1875. Washington, 1879.

Presented by Prof. J. R. Soley, Librarian, Navy Dept., U. S.

Eyferth, B. Naturgeschichte der Mikroskopischen Süsswasserbewohner. Braunschweig, 1885. Presented by Goeritz und Zu-Putlitz, Publishers.

Fairholt, F. W. A Dictionary of Terms in Art. London.

Fischer-Treuenfell, R. von. Die Kriegstelegraphie in den neueren Feldzügen Englands. Berlin, 1884. Presented by the Author.

Fisheries of the State of New York. First, Fifth, Sixth, Seventh to Thirteenth Annual Reports of the Commissioners. Albany, 1869-84.

Presented by the Commissioners.

Fitchburg Railroad Company. Annual Reports of the Directors. 1873-84. Boston. Presented by the Directors.

Fonografic Corespondent and Reporter for de yer 1846. Vol. 3. Lundun, 1846. Presented by H. T. Child.

Fonografic Reporter for de yer 1851. Lundun.

Presented by H. T. Child.

Forests of North America. Report. By Chas. S. Sargent. Census Report. Vol. 9. Washington, 1884. Presented by the Dept. of the Interior.

Friends Free Library and Reading Room, Germantown. Annual Report and Catalogue of New Books. 1885. Presented by the Librarian.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXI. APRIL, 1886. No. 4.

TORNADO STUDY—ITS PAST, PRESENT AND FUTURE.

BY LIEUT. JOHN P. FINLEY, U. S. SIGNAL CORPS.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *November 27, 1885.*]

The systematic study of tornadoes as such, and as the term is now technically applied to severe local storms, is of comparatively recent origin. The funnel-shaped cloud, however, had been observed and described by intelligent persons in this country, so far as our records show, as far back as 1761. The storm in question occurred at Charleston, S. C., and was one of remarkable violence. About 2 P. M., on the fourth of May, this terrible phenomenon was first seen by many of the inhabitants of Charleston coming down Wappoo Creek, the cloud resembling a large column of smoke and vapor. In the course of its path every tree and shrub was torn up. Great quantities of leaves, branches, and timbers were seen furiously driven about and agitated in the body of the moving column of cloud. The sky was overcast and cloudy all the

forenoon. About 1 o'clock it began to thunder, followed by heavy clouds and more thunder. The day (particularly in the afternoon before the storm) was very sultry and oppressive. Shortly after the storm, the wind was "quite fallen," the sun shone out and the sky was clear and serene. The direction of progressive movement of the cloud was from S. W. to N. E.

The width of path is given as 300 fathoms (about 1,800 feet). The account further informs us that though such storms were very unusual in Charleston, yet vestiges of the tremendous power of the whirling cloud could be seen in the wooded country about the town, both in that and in neighboring "provinces."

Here we have a most interesting and intelligent account of a tornado occurring nearly 125 years ago, and evidence of the appearance of these storms at a much earlier date, in South Carolina.

Another remarkable tornado was observed and described by the Rev. Dr. Stiles, of Yale College, as occuring at Northford, Conn., June 19, 1794. The observer was about 100 yards distant from the cloud while it passed. It was a circular figure whirling most violently upon its centre. From the midst of the cloud issued a "vortex of air," much in the form of an hour glass, which alternately contracted and expanded from ten to twenty rods. The hour-glass form of the cloud at the earth, had constant communication with the cloud above. When it contracted it became less violent, but when it expanded, the scene was frightful and destruction filled the air.

In 1842, Prof. Loomis, of Yale College, prepared and published in Silliman's Journal, Vol. 23, a list of 19 tornadoes, occurring during the years 1823 to 1842, in the following States: Mississippi, 4; Ohio, 3; Tennessee, 2; New York, 4; Connecticut, 1; Rhode Island, 1; North Carolina, 1; New Jersey, 1; and Alabama, 1.

In Europe, we find very early records of storms that appeared to possess the characteristics of our tornadoes of to-day. In A. D. 793, "dire fore-warnings came over the land of the Norththumbrians, (England) and terribly terrified the people; these were excessive whirlwinds, with dragon-like tails." Here the spout-like form of the cloud is referred to.

In the year 1090, it is recorded that in England a violent tornado overturned 606 houses.

About the first specific date of a storm is the one that occurred

on the fifth of October, 1091, in England. It passed from S. W. to N. E., and the sky was dreadfully dark. Many churches fell, and in London over 500 houses were destroyed.

On the eighth of April, 1838, a tornado passed within three miles of Calcutta, British India; width of path, one-quarter mile; direction of movement, S. 37° E. The tiles of the terraces laid in the best cement were ripped up as if by suction. As a most extraordinary proof of the lateral force of the wind, a slight bamboo was driven horizontally through one of the raised tiled walks which pierced through the whole breadth, breaking the tiles on both sides. These tiles were made of baked earth, five feet thick. The tornado formed about 2 P. M., and passed through twenty-six villages from Arundpore to Hurreennabhee, a distance of sixteen miles, destroying 1,245 houses, 215 people and 533 head of cattle.

At Chatenay, near Paris, in June, 1839, a violent tornado occurred shortly after mid-day. The cloud assumed the form of a funnel, the small end reaching the earth. Everything in its path was completely swept from the earth.

This record might be greatly augmented had I the time to devote to it, in this brief résumé of the subject.

We thus find that the tornado (the unmistakable and characteristic funnel-shaped cloud) has been observed and recorded more or less faithfully, for over 130 years in this country, and for centuries in Europe and parts of Asia.

Let us consider for a moment the names of those who have given some attention to this subject, in most cases, prior to the commencement of the study by the Signal Service. I refer now to the United States.

Rev. Dr. Stiles, of Yale College, prepared a brief description of the tornado of June 19, 1794, at Northford, Conn.

Prof. Wm. C. Redfield made a brief study of the tornado of August 30, 1838, at Providence, R. I.

Prof. Robert M. Hare, of the University of Pennsylvania, in 1838.

Prof. Olmsted, of Yale College, a tornado at New Haven, Conn., July 31, 1839.

Prof. Elias Loomis, of Yale College, a tornado at Mayfield, O., August 4, 1842. Also a tornado at Stowe, O., October 20, 1837.

Prof. O. N. Stoddard, of Miami University, Ohio, a tornado at Brandon, O., January 20, 1854.

Prof. James Espy, a tornado at New Brunswick, N. J., June 19, 1835.

Prof. Brewer, of Yale College, in 1878.

Dr. J. H. Kain, of Tennessee, a tornado at Shelbyville, Tenn., June 14, 1830.

John Chappellsmith, of Indiana, a tornado at New Harmony, Ind., April 30, 1852.

Dr. Ezra Michener, of Toughkenamon, Pa., in 1877.

Prof. Richard Darlington, Jr., of Ercildoun, Pa., in 1877.

Prof. Farrar, of Cambridge, in 1815.

Prof. Wm. Blasius, Philadelphia, a tornado at West Cambridge, Mass., August 22, 1851.

Prof. Francis E. Nipher, of Washington University, St. Louis, a tornado at Collinsville, Ills., April 14, 1879.

Hon. T. H. Van Horn, Kansas City, Mo.

Prof. W. W. Daniels, of University of Wisconsin, the Wisconsin tornadoes of May 23, 1878.

Prof. Jno. H. Parker, Topeka, Kans.

Dr. Gustavus Hinrichs, of the University of Iowa, and Director of the Iowa State Weather Service.

Col. C. Shaler Smith, Chief Engineer of the St. Louis Bridge.

Silas Bent, St. Louis, Mo.

Judge Jameson, District Courts, Chicago, Ills.

Prof. M. W. Harrington, University of Michigan.

Prof. J. H. Macomber, State Agricultural College, Iowa.

Prof. Richard Mansill, Rock Island, Ills.

Prof. Elisha Gray, Chicago, Ills.

John A. Tice, St. Louis, Mo.

Prof. J. T. Lovewell, University of Kansas.

Prof. T. C. Mendenhall, Director of the Ohio State Weather Service.

Prof. W. D. Davis, Cambridge, Mass.

Prof. Wm. Ferrel, United States Coast and Geodetic Survey.

The work here represented, with few exceptions, was confined to brief descriptions and investigations of individual storms.

From Europe comes a large mass of literature on the subject of revolving storms, including tornadoes. Some of the more im-

portant writers on this subject may be mentioned as follows: Bohun, Blanford, Elliott, Meldrum, Scott, Piddington, Reid, Willson, DeChevrells, Becquerel, Faye, Peltier, Poey, Fourrelt, Martins, Bebber, Dove, Hirn, Köppen, Knipping, Reye, Oersted, Schück, Boscorich, Vines, Mohn, Celoria and Zantedeschi. Of all the names here mentioned, none gave the subject of tornadoes any special attention, except perhaps, Poey, Faye and Mohn.

It will now be opportune to consider, in brief, what the Signal Service has accomplished, by observation and investigation. We will now define what we mean by the word tornado, and how we shall distinguish this storm from others which are known to us and possessed of prominent characteristics.

THE TORNADO.

The general direction of movement of the tornado is invariably from a point in the southwest quadrant to a point in the northeast quadrant. The tornado cloud assumes the form of a funnel, the small end drawing near to, or resting upon, the earth. This cloud and the air beneath it revolve about a central vertical axis, with inconceivable rapidity, and always in a direction contrary to the movement of the hands of a watch. The destructive violence of the storm is sometimes confined to a path a few yards in width, as when the small, or tail-end, just touches the earth; while on the other hand, as the body of the cloud lowers, more of it rests upon the earth, the violence increases, and the path widens to the extreme limit of eighty rods. The tornado, with hardly an exception, occurs in the afternoon, just after the hottest part of the day. The hour of greatest frequency is between 3 and 4 P. M. Tornadoes very rarely, if ever, begin after 6 P. M. A tornado commencing about 5 P. M. may continue its characteristic violence until nearly 8 P. M., which means only that the tornado cloud may be travelling after 6 P. M, or after 7 P. M., but it does not develop; that is, make its appearance for the first time after those hours. Outside of the area of destruction, at times even along the immediate edge, the smallest objects often remain undisturbed, although at a few yards distant the largest and strongest buildings are crushed to pieces. At any point along the storm's path, where there is opportunity afforded the tornado cloud to display its power, the disposition of the débris presents unmistakable signs of

an action of the wind, such as might be called a rotation, from the right through the front to the left around the centre. The destructive power of the wind increases steadily from the circumference of the storm to its centre.

Observations with a single isolated barometer will not indicate the approach of a tornado, however near the position of the instrument to the path of the storm, but such observations are of value when a number are displayed upon the daily weather map.

THE CYCLONE.

This term was originally employed by Piddington to characterize the typhoon of the China Seas. As employed by the Signal Service, it applies to the broad, violent storms such as reach the South Atlantic and Florida coasts from the West Indies.

Cyclones have a varying width of path from 100 to 1,000 miles. Their course of progressive movement is a parabolic curve which trends northwestward from the West Indies, under the influence of the Northeast trades, and the general drift of the atmosphere until they reach the vicinity of parallel 30° N., when they slowly curve to the Northeast, continuing in that direction, either along the coast, or at a short distance inland. The storm finally disappears to the Eastward in the vicinity of parallel 50° N.

Within the storm area, the air does not actually move or whirl in a circle: there is only a tendency to such a movement about the region of lowest barometer.

Cyclones are otherwise characterized by sudden rapid and unusual oscillations of the barometer, heavy precipitation, heavy ocean swells and high straight wind velocities, which frequently exceed 100 miles per hour. The violence of the storm increases from the circumference towards the centre, reaching its maximum about midway between the centre and circumference of the storm. At the centre of the cyclone, nearly a dead calm prevails.

THE HURRICANE.

Although it seems hardly necessary to define the hurricane, it will, perhaps, be well to state that, as here considered, it means a straight wind of extraordinary velocity. They may, and frequently do, occur without the accompaniment of any precipitation. On the summit of Mount Washington, White Mountains, N. H., a measured velocity of nearly 200 miles per hour, has been

recorded. On the summit of Pike's Peak, Rocky Mountains, Col., a measured velocity has several times exceeded 100 miles per hour. On the coast of the Carolinas, maximum measured velocities have ranged from seventy-five to 160 miles per hour. In the Eastern Rocky Mountain slope, and in the lake region, measured velocities are sometimes recorded ranging between sixty and eighty miles per hour. This storm may be known as the Blizzard of the Northwest, the Chinook of the Northern Plateau, the Norther of the Southern Slope and Texas, or the Simoon of the Desert. Hurricanes may occur at any hour of the day or night, and in any month of the year. The most violent, however, take place during the spring and autumn. The width of the path of the storm is very irregular, and may vary from many rods to many miles. In either case, the velocity at all points within the storm's path is not necessarily the same; in fact, such a condition never occurs. The duration of the storm is also extremely variable; it may continue for only a few minutes or for several hours, although, in the latter case, the maximum velocity is not maintained throughout the entire period. On the contrary, there are periods of recurrence alternating with decided diminutions of the highest activity. There are, perhaps, but few portions of the country altogether free from the possibility of their occurrence. In the low table lands of mountainous regions, where most of the country is extremely broken, the habitable portions are shielded from the power of violent wind storms. No surface currents can attain any great velocity in such regions, although, on the mountain peaks and elevated plateaus, dangerous hurricanes at times prevail.

THE WHIRLWIND.

In defining this phenomenon it will be best perhaps that you should be asked to recall the occurrence, on any warm day, of the formation of a dust-whirl as it suddenly bursts upon you in the open street, fairly enveloping your body with fine particles of dirt, straw, leaves, and the like. Whirlwinds suddenly start up from some barren, sandy spot unduly exposed to the direct rays of the sun. Over a small surface thus exposed the air rapidly rarifies and ascensional currents form which move spirally inward and upward, carrying dust, leaves, straw and sometimes objects of considerable weight. The air within the whirl moves either from left to right

or in the contrary direction. The whirlwind's path has a diameter of several feet (sometimes rods) and the direction of its course of movement is decidedly irregular, possibly moving toward any point in the compass. On the sandy plains of Arizona, Southern California and Nevada these phenomena occur with great frequency during the summer months. Columns of whirling sand, sometimes several in a group, move rapidly over the surface. Whirlwinds are harmless and generally of but a few moments duration. In comparison with the tornado, let it be borne in mind that the former starts from the earth's surface, extending upward and moves onward, not leaving the earth, being solely confined to the region of surface currents. The tornado forms near the superior limit of the lower regions of the atmosphere and between the upper and lower sets of currents prevailing in the upper and lower regions of the atmosphere. The former currents are indicated by the appearance of the fine cirrus clouds and the latter by the heavy cumulous formation. From this lofty seat of origin, the tornado cloud gradually descends to the earth's surface, increasing rapidly in size and augmenting in power.

WATER-SPOUTS.

These disturbances generally form at a considerable height in the air, although at times they seem to ascend from the water's surface; that is to say, there is no visible agent influencing the ascension of the water, but, of course, in every instance the causative power is from above, and in the latter case, near the water's surface. When I speak of the formation of the water-spout at a considerable height in the air, I mean that the embodiment of the whirl, or the revolving current of air, first appears as a dark cloud of minutely divided particles of water, the result of rapid condensation, of course in the air, and, therefore, above the water. The swift passage of the air in a spirally, upward motion over the surface of the water raises it in the form of spray and carries it upward in the centre of the whirling cloud, which then presents the appearance of a densely opaque body, and conveys an impression to the eye of the observer that a huge column of water is ascending in the form of a long spout, widening gradually toward the top. There are instances, however, where the force manifested was sufficient to raise a considerable quantity of water several hundred

feet in the air. Water-spouts form during periods of excessive heat, generally in the afternoon, and at or near the hottest part of the day. In the temperate zone, they only occur during summer months.

They are of most frequent occurrence in the region of calms between the Tropics, but are not altogether strange sights in the Gulf of Mexico and along the Gulf stream, south of parallel 40° N. In regard to motions, they possess both a rotary and progressive action, but in neither do they manifest a permanency of direction. Water-spouts cannot be considered as altogether harmless, for there are instances where vessels have been wrecked by them.

HAIL STORMS

Are peculiar atmospheric disturbances, which, in regard to the dimensions of their paths, are, next to the tornado, the most circumscribed of all storms, save the whirlwind. They are characterized by a strange cloud formation and a peculiarity of precipitation unlike any other phenomena in the category of storms. The cloud from which the hail falls is basket-shaped, with a dark and portentous exterior, a ragged and ominous-looking opening at the bottom, and within, a whirling conglomeration of snowflakes, pellets of snow and ice, partly formed hailstones, the latter of an almost infinite variety of shapes The hail cloud forms between the currents of the upper and lower regions of the atmosphere, and moves forward in the plane of these currents, either within or just above the upper limit of the lower atmospheric regions, where it finally disappears and the deposition of hail ceases. The path of the storm as indicated by the distribution of the hailstones, is, at times, very narrow, although the range of width is decidedly inconstant, varying from one to fifteen miles. The hail storm travels quite rapidly, from thirty to fifty miles per hour, and the length of its path is even more variable than the diameter, ranging as it does from ten miles to two or more hundred. The direction of the course pursued by the storm is always from some point West to some point East. It may be from Northwest to Southeast, or from Southwest to Northeast. Hail storms may occur at any time of the day or night, although they are most frequent in the afternoon, just after or near the hottest part of the day.

They are most prevalent in that region of country embraced

between the parallels of 30° and 50° N. South of parallel 30° N. hail storms are of rare occurrence at the level of the sea, but at the height of 100 or 200 feet they occur more frequently, and in the mountains of British India they are very common, the hailstones being usually of large size. Hail storms are not necessarily confined to the land areas, but may and frequently do occur over large and small bodies of water.

THUNDER STORMS.

These phenomena are atmospheric disturbances of great variability of extent and power. They are invariably accompanied by such manifestations of the presence of electricity as are ordinarily termed thunder and lightning, the former being entirely consequent upon the existence of the latter. Thunder is but the reverberations of the concussion produced by the inconceivably rapid propulsion through the air of that physical element we are pleased to term electricity. Thunder storms may be a few miles or several hundred in extent, and their length of duration is quite as uncertain, viz.: From a few hours to one or more days. There is no regular time of day for their occurrence, although they are, perhaps, more frequent in the afternoon. However, they may occur at any time during the day or night. As to the season of year, summer is the period of greatest prevalency. There is no month of the year entirely free from them. Whether the precipitation be rain or snow, the presence of electricity has still been manifested in the usual form. With the former character of condensation of vapor, the evidence of electricity is most common, while with the latter it is the rare exception. A valuable paper on this class of storms has lately been published by Prof. Hazen, of the Signal Service.

As regards geographical distribution, thunder storms are most frequent between the equator and parallel 40° N., and from thence to parallel 70° N., the average frequency diminishes with considerable rapidity. In the vicinity of parallel 80° N. it is believed they never occur, although this in the main is mere supposition. There are certain portions of the United States where thunder storms are unusually frequent as compared with other parts. They seldom occur in the Pacific Coast States, especially California, and are most frequent and violent in the Eastern Rocky Mountain Slope, the lower Missouri Valley and in the Lake Region.

Having briefly outlined the characteristics of the various classes of storms well known to the United States, we will now proceed to consider the subject of our paper—the dreaded tornado. Right at this point I must refrain from entering too largely into interesting details for fear of making this paper too prolix. At this stage of our inquiry in regard to the character and classes of storms, I presume it will be admitted, that no two of the several storms defined, at least *appear* to be alike. There are, however, points of resemblance and in some, these features are stronger than in others. As each is studied more carefully, the essential points of difference, if any, will be more clearly contrasted. It is not within the province of this paper to discuss at *length* the points of difference or harmony, nor enter into an intricate analysis of meteorological phenomena and the multiform operations of atmospheric changes attending the origin, development and complete formation of these disturbances.

Let us examine into the methods of investigation pursued by the Signal Service and trace the progressive development. It was first necessary to gather the facts. This required field-work and the careful examination of the entire track of a tornado. At first this individual investigation was faulty in that it lacked system, and a thorough knowledge of what was wanted. The tendency in isolated investigations was to seek the sensational features of the occurrence and ignore the methods leading to the discovery of important truths. Thorough field-work produced its rewards. Aided by the records of past tornadoes embracing descriptions more or less complete, the investigator was enabled to classify the data within reach and watch for coincidences and relations which paved the way for conclusions, which provided the means of arranging a more systematic method of conducting individual investigations.

Field-work was continued by a representative of the Signal Corps until it was found that the burden was too great for one man, and the results were not commensurate with the expenditures. Field-work, however, must continue, but another plan was necessary to make it effective. Out of this necessity grew the present large and efficient corps of Tornado Reporters for the Signal Service, numbering about 1,500 all told.

The establishment of this special corps of observers became

necessary in order to gather the exact information desired with the least possible delay. The largest number of stations are necessarily located in those States in which tornadoes are of the most frequent occurrence. The peculiar geographical distribution of tornadoes necessarily limits our study to certain States that are frequently visited, and other portions seldom, if ever, visited by tornadoes. In the regions of greatest frequency the stations number from two to four in each county, depending upon its area. Tornado reporters, in return for their voluntary contributions, are supplied with the tornado publications of the Signal Service; they are also furnished with instructions and materials necessary for the taking, recording and mailing of observations and reports. Reports are forwarded to the Chief Signal Officer as soon as possible after the occurrence of a tornado, and consist of detailed descriptions, instrumental observations, photographs, diagrams, charts, and illustrations. While attention is principally given to the examination and report of tornadoes for the current year, each tornado reporter is instructed to work up the past history of these storms in his State, making careful search after any facts relating to windfalls, or other traces of past tornadoes.

Some of the results sought to be obtained by the above method of investigation may be briefly given as follows:

(1.) To determine the origin of tornadoes and their relation to other atmospheric phenomena.

(2.) To determine the geographical distribution of tornadoes and their relative frequency of occurrence in different States, and in different parts of the same States.

(3.) To determine the conditions of formation with a view to the prediction of tornadoes.

(4.) To determine the means of protection for life and property.

(5.) To determine the periodicity of the occurrence of tornadoes and their relative frequency by seasons, months, parts of a month, and time of day.

(6.) To determine the prevailing characteristics of tornadoes.

(7.) To determine the relation of tornado regions to areas of barometric minimum.

(8.) To ascertain yearly the loss of life and property in the various tornado districts and its effect upon the industries of the people.

(9.) To ascertain the influence of topography upon the occurrence and movement of tornadoes.

(10.) To determine the influence of rainfall and forests upon the development of tornadoes.

(11.) To ascertain the relations of tornadoes to hail storms, thunder storms, and hurricanes.

While the inductive stage of the work is receiving earnest and unabated attention, the deductive demands and receives as much consideration as limited means will permit. More is demanded in this direction than the means at hand will provide for. It cannot be wondered at that the public are clamorous for results, yet, if the scope of their charity was only measured by the extent and variety of their demands upon the Service, ventures could be made and results arrived at that otherwise remain in the dark until the methods by which they are obtained have been tried in the furnace of fire, hung up to cool and then tested again. However, it pays to summer and winter every important deduction before you declare its truth to the world.

We have now hunted the tornado in its lair, we have elaborately sketched and worked out its details of horror, devastation, singular characteristics, mighty force and many of its peculiar mysteries.

What can we hope for as the result of this work, this acquisition of knowledge in details? Some have said: Study one tornado thoroughly and you have exhausted the subject. But this is a narrow and hopeless view of the situation. It is a weak confession that difficulties cannot be successfully encountered. Had we stopped at this point some years ago, the possibilities of prediction would have remained a myth, and many important truths sealed among the clouds. Persistent labor has opened a portion of the winding pathway and revealed some of the hidden secrets, preparing the way for others of still greater intricacy. Still the question is asked, what can we do with the tornado? it comes and goes with the lightning's flash and strews its pathway with the horrors of death and desolation. Many plans have been devised and submitted, but never tested, to destroy the violence of a tornado. The author, or inventors, in most cases lacked confidence in their own handiwork, while in other instances the scheme was so uncertain and of such magnitude that a government must supply the means for experiment, and efforts to obtain such assistance has always proved unsuccessful.

We have not entered as a competitor in this field. After a careful survey of the possibilities, such as they appeared at the time, it was considered impracticable to employ any means to destroy the tornado cloud, or to adopt any line of work involving destruction of cloud, or preventation of formation.

We have taken the tornado as it is, admitting certain things, contesting others, looking at it as a scientific problem with two sides: one practical, the other abstract and purely scientific. The questions involved in both are extremely important and require for their elucidation the most patient and laborious methods of investigation. In any event, our work must show a determined effort to be beneficial, with reasonable assurance that such efforts will prove successful. In what direction can such results be accomplished? The answer is, in the forecasting of conditions favorable for the development of tornadoes. This is, at present, the great desideratum from both a practical and scientific standpoint. Tornado prediction involves the most intricate study of atmospheric phenomena. The successful prediction of a tornado will not of itself prevent the destruction of buildings, crops and machinery, but it will give opportunity for preparation to protect such property, and more than all that, it will provide against the destruction of life, and much personal property, the latter in the shape of valuables, that are readily moved from place to place. Not least among the advantages to accrue from forecasting is the relief from undue excitement, and anxiety in those sections of country where the tornado is of frequent occurrence. A person who has not witnessed the feeling prevailing at such places during the tornado season, can have no conception of its direful influence and depressing effect. The approach of every black cloud on the horizon, or the sudden freshening of the wind are danger signals to the majority of the people, and consternation prevails at once. Factories and shops close, and business is paralyzed for the day. This great loss to mind, body and estate is repeated many times during the tornado season, when there is really not the least sign of a tornado. But only the eye of the student of the weather map can detect the lurking indications of tornado development.

By admitting the exclusiveness of map study, I do not mean to deny that there are important atmospheric conditions which the isolated observer may carefully watch and study with profit, as for

example: the gradual setting in and prolonged movement of the air from the north and south points; the gradual, but continued fall of the thermometer during the prevalence of the former currents, and a rise during the predominance of the latter.

If the northerly currents are the prevailing air movements at the place of observation, the atmospheric disturbance is forming southward, but, if the prevailing currents are from the South, then to the northward of the observer.

Carefully study cloud development, color as well as form; also, manner and direction of approach. Clouds render visible the air currents, and are full of meaning. A study of the currents of the atmosphere would be impossible without their existence, and that, too, in a variety of forms. Dispense with cloud formation, and the face of the sky would become blank, and severe storms no longer visible.

Wind direction, temperature, and clouds, are proper subjects of observation and investigation by the isolated observer. The barometer is of less importance in this line of inquiry, unless the barometric observations can be promptly compared with those taken at other points near by and at the same moment of time. The tornado itself is an extremely local affair, and the accompanying barometer changes do not affect a large extent of country. Probably if a barometer were placed in the immediate track of the tornado cloud, it would not, with any certainty, indicate the presence of the storm until the crashing winds had fallen upon the instrument.

Having asserted and briefly shown that tornado prognostications may be valuable and beneficial, the question is asked can they be successfully made? The reply is in the affirmative. There are, however, several difficulties to be encountered, not incident to the preparation of general weather predictions.

The following are most of the features of map study that must receive consideration in the preparation of a tornado prediction for any day.

(1.) Barometric Trough. Region. Ratio of Axes. Pressure. Departure from Normal.

(2.) Central Area of Barometric Minimum. Region. Pressure. Departure from Normal.

(3.) High Contrasts of Temperature. Region. Gradient.

(4.) High Contrasts of Cold Northerly and Warm Southerly Winds. Region.

(5.) High Contrasts of Dew-point. Region. Gradient.
(6.) Heaviest Lower Cloud Formation. Region. Kind.
(7.) Opposing Movement of Lower Clouds. Region. Directions.
(8.) Coincident Movement of Upper and Lower Clouds. Region. Direction.
(9.) Opposing Movement of Upper and Lower Clouds. Region. Direction.
(10.) Opposing Movement of Lower Clouds and Winds. Region. Direction.

I cannot lead you through the details of this work within the scope of this paper. Sufficient to say that the work affords gratifying results as will be shown.

Tornado prediction is no longer a possibility, but in many respects may be considered an accomplished fact. By this I do not mean absolute perfection, but reasonable success. The system of preparation and study which leads to the result is subject to improvement, both as to manipulation of charted data and the verification of forecasts. It is believed that the work now in hand, with the above end in view, will greatly advance the present measure of success.

Beginning with the year 1884, the daily weather maps were closely studied to determine the conditions favorable for the development of tornadoes. On the tenth of March, 1884, regular tornado predictions were commenced experimentally, and during the remainder of the month were made twice daily at intervals of eight hours. The first prediction was made from the morning (7 A. M. Washington time) weather map and embraced the eight hours up to 3 P. M. The second prediction was made from the afternoon (3 P. M. Washington time) weather map, and embraced the eight hours up to 11 P. M.

For the month of April, the same plan was followed.

For the month of May, June and July only one prediction daily was made. This prediction resulted from a study of the 7 A. M. (Washington time) weather map and embraced the sixteen hours up to 11 P .M. Tornado predictions were made for certain districts. That portion of the United States lying between the seventy-seventh and 102d meridians was divided into eighteen sections or districts. Tornado predictions for the year 1885 began June 1st and terminated September 20th. These predictions were made from a study of the 7 A. M. (Washington time) weather map and embraced the sixteen hours up to 11 P. M.

In preparing for the work of making tornado predictions, it was

necessary to ascertain as nearly as possible the limits of that portion of the United States within which tornadoes were most likely to occur. These limits were determined from the geographical distribution of tornadoes, as taken from the records of the past ninety years. Each district was subdivided by imaginary lines into four equal parts, and predictions were made either for the entire district, or for any one, or more, of these parts. As a whole, this study proved fairly successful for the period during which the work progressed. In no instance where it was predicted that conditions were favorable for the development of tornadoes did violent storms fail to occur, either hail, hurricanes, or tornadoes. But no prediction was considered entirely successful unless the characteristic funnel-shaped cloud was actually reported as a feature of the storm, and that the tornado's path was clearly within the region, or district, for which the prediction was made, and that the tornado occurred within the eight or sixteen hours specified in the prediction. All of the most remarkable and destructive tornadoes of the two seasons were predicted for the districts within which they occurred from five to eight hours in advance of their appearance. It was not considered advisable to furnish these predictions to the public at the time they were made, because the work was undertaken experimentally, as a matter of study and official record, with a view of ascertaining what might be accomplished in this direction for the benefit of the agricultural sections of the country.

In what follows there is presented in concise form some of the most important results that have been attained by the methods of investigation already pursued:

(1.) That there is a definite portion of an area of low pressure within which the conditions for the development of tornadoes is most favorable, and this has been called the dangerous octant.

(2.) That there is a definite relation between the position of tornado regions and the region of high contrasts in temperature, the former lying to the south and east.

(3.) That there is a similar definite relation of position of tornado regions and the region of high contrasts in dew-point, the former being, as before, to the south and east.

(4.) That the position of tornado regions is to the south and east of the region of high contrasts of cool northerly and warm southerly winds—a rule that seems to follow from the preceding,

and is of use when observations of temperature and dew-point are not accessible.

(5.) The relation of tornado regions to the movement of upper and lower clouds has been studied and good results are still hoped for.

(6.) The study of the relation of tornado regions to the form of barometric depressions seems to show that tornadoes are more frequent when the major axis of the barometric troughs trends north and south, or northeast and southwest, than when it trends east and west.

(7.) The general direction of movement of the tornado is invariably from a point in the southwest quadrant to a point in the northeast quadrant.

(8.) The tornado cloud assumes the form of a funnel, the small end drawing near, or resting upon the earth.

(9.) The cloud and the air beneath it revolve about a central vertical axis with inconceivable rapidity, and always in a direction contrary to the movement of the hands of a clock.

(10.) The destructive violence of a tornado is sometimes confined to a path a few yards in width, or it may widen to the extreme limit of eighty rods.

(11.) The tornado, with hardly an exception, occurs in the afternoon, just after the hottest part of the day.

(12.) The hour of greatest frequency is between 3 and 4 P. M.

(13.) The destructive power of the wind increases steadily from the circumference of the storm to its centre.

(14.) Observations with a single isolated barometer will not indicate the approach of a tornado, however near the position of the instrument to the path of the storm, but such observations are of value in this connection only when a number of them are displayed upon the daily weather map.

(15.) The tornado season is embraced between the first of April and the first of October. There are, however, instances in a long series of years where tornadoes have been reported in every month of the year.

(16.) The months of greatest frequency are June and July.

(17.) Taking the whole United States together, it is found that the region of greatest frequency per year per square mile embraces the following States: Georgia, South Carolina, Illinois, Indiana, Iowa, Kansas, Missouri, Ohio and Wisconsin.

(18.) The movements of a tornado cloud are comprised within limits of four peculiar and distinct motions. Knowing these and obeying the rules given in Signal Service Notes No. XII as to his movements on the approach of a tornado cloud, no person need suffer injury or death from the fury of the storm.

(19.) No buildings however strong have yet been able to withstand the violence of a tornado.

(20.) People must resort to dug-outs and cellar caves, the preparation and use of which is indicated in Signal Service Notes No. XII, in order to place themselves and their valuables beyond the possibility of danger.

(21.) Under no circumstances, whether in a building or a cellar, take position in a northeast room, in a northeast corner, in an east room, or against an east wall, remembering that the tornado cloud invariably moves in a northeasterly direction.

(22.) The concomitants of the tornado are: An oppressive condition of the air, the gradual setting in and prolonged opposition of northerly and southerly currents over a considerable area, a gradual but continual fall of the thermometer, with a prevalence of the northerly currents, and a rise with the predominance of the southerly. Decided contrasts of temperature north and south of the line of progressive movement. Huge masses of dark and portentous clouds in the northwest and southwest, possessing a remarkable intensity of color, usually a deep green. A remarkable rolling and tumbling of the clouds, scuds darting from all points of the compass toward a common centre. Hail and rain accompanying the tornado, the former either in unusual size, form or quantity, and the latter either remarkable in quantity or size of drops. The presence of ozone in the wake of the tornado. A remarkable roaring noise, like the passage of many railroad trains through a tunnel. The clouds generated by the vortex assume the form of a funnel, with the smallest end toward the earth. The remarkable contraction of the storm's path; the remarkable definiteness of the limits of the storm's path. Upon reaching the earth's surface, the vortex assumes the form of an hour-glass. The vortex has four motions, viz: (1.) The whirling or gyratory motion, always from right to left; (2.) The progressive motion, generally from some point in the southwest quadrant to some point in the northeast quadrant; (3) The ricochet motion; (4.) The oscillatory motion.

(23.) The characteristic effects of a tornado are: Objects are drawn towards the vortex from every point of the compass. Objects passing into the vortex are thrown upward and outward by the vortical action of the engaged air. Structures are literally torn to pieces by the vortical action of the air, evidence of which is afforded both by the fineness of the débris, and also its disposition in the storm's path. The débris is thrown inward from each side of the storm's path. Light objects are carried to great heights, and also to great distances. Objects are carried inward and upward by the centripetal and outward by the centrifugal force of the vortex. Weight or size are conditions which generally present immaterial values to the power of the tornado. Persons are stripped of clothing. Fowls and birds are denuded of feathers and killed. Trees are whipped to bare poles. Long and heavy timbers are driven to considerable depths in the solid earth. The vortex is completely filled with flying débris. Timbers are driven through the sides of buildings. Sand and gravel are driven into wood. Human beings and animals are run through with splinters and timbers. Straws, bits of glass, and pieces of metal are driven into wood. The strongest trees are uprooted or twisted off near the roots. Men and animals are terribly mangled by contact with flying débris, and by being rolled over the ground for considerable distances. In the path of the storm all vegetation is destroyed. Railroad trains are thrown from the track. Iron bridges are completely dismantled and carried from their foundations. Heavy bowlders, weighing tons, are rolled along the earth. The largest railroad engines are lifted from the tracks on which they rest. All objects, whether metal or non-metallic, magnetic or non-magnetic, simple or compound, animate or inanimate, are acted upon in a similar manner.

(24.) Cheap buildings, dug-outs and cellar caves, with general insurance, is recommended as the wisest policy to be pursued by people living in the tornado districts. During the past four years tornado insurance companies have been formed, and tornado risks have been written by several large companies engaged in other branches of insurance. Within the period above indicated tornado risks have been taken to the amount of about \$50,000,000 in the tornado districts of the country, principally in the West. The terrible loss of life and property which follows in the wake of a

tornado, and the intense suffering and misery endured by those who survive its perils, only to find that all their worldly goods have been swept away, makes this storm one of the direst calamities that can befall a community. Hundreds of thousands of dollars' worth of property are destroyed in a few hours and scores of persons killed, or maimed for life, along the track of a single tornado.

The study of the origin, nature and the laws governing the development and movements of this class of local storms is of the utmost interest to the agricultural sections of the tornado districts. The work already accomplished has been received with great satisfaction by the people living in the regions traversed by these storms. During the year, numerous letters have been received from nearly every State in the Union, testifying to the progress and success of the work.

Another evidence of the importance and success of the work is that illustrated by the existence of a large corps of voluntary observers, and the enthusiasm manifested by them in the work upon which they are engaged. In many instances tornado reporters have made unusual efforts to obtain exact information concerning the peculiarities of a storm, and in some cases have fitted out at their own expense surveying parties, for the purpose of carefully and accurately investigating the entire track of a single tornado, extending, maybe, a distance of from thirty to 100 miles. All of this information is received by the Chief Signal Officer in Washington, without other expense to the Government than the cost of blank forms, envelopes, wrappers and printed instructions. The data thus collected during each tornado season are carefully studied and prepared for publication with the view of placing it before the people of the tornado districts in the most practicable form and with the least possible delay. The published results of each year's work should reach these people before the opening of the next tornado season, if possible, for the information contained therein may prove of great benefit to guard against the dangers of another season. But present appropriations do not provide the necessary means.

The information above referred to does not include that to be obtained through the medium of tornado predictions, which, if made, should be furnished to the public each day through the

agency of the telegraph. More can be realized from the work of tornado predictions when we have established a normal average of occurrence for each tornado district. This normal will be founded upon the results obtained from a very faithful record of the entire region embraced, for a chronological period of at least twenty-five years. I am now engaged upon this work, and hope that by the opening of the tornado season of 1886 I shall have the necessary data completely available.

In the study of tornadoes it has become necessary to undertake something more than a simple record of their occurrence or an occasional investigation of those that are attended with unusual destruction to life and property. A practical knowledge of the nature of these storms is a matter of the utmost interest to the inhabitants of the tornado districts; and not least among the objects aimed at by the Chief Signal Officer in directing the continuance of tornado investigations is to allay any needless anxiety or fear on the part of those people living in the regions most frequented by tornadoes. Methods of observations based on reports from stations situated from 100 to 200 miles apart, as in the case of cyclones and hurricanes, are inadequate to develop the mysteries of the funnel-shaped cloud.

BREAD FERMENTATION.—Aimé Girard communicates to the French Academy the result of experiments undertaken to show whether the rising of bread is due to a spirituous fermentation, or whether that hypothesis should be rejected, as some eminent savants now think. In some of the experiments, yeast was employed, in others leaven. The amount of gas and the relative proportions of carbonic acid, oxygen and nitrogen were carefully noted, as well as the quanity of alcohol produced. The results represent, as exactly as one could wish, the requirements of Pasteur's equation of alcoholic fermentation.—*Comptes Rendus, Sept. 14, 1885.*

REPORT ON METEORIC DUST.—Experiments have been made at the Scottish Marine Station, by means of an apparatus in which the wind blows through gratings of fine platinum wire. The moisture deposited is collected and examined for suspended particles. Funnels have also been placed at different localities for catching rain. Carbonaceous matter is most common. In smaller quantities occur quartz, feldspar, mica, turmaline, garnet, volcanic dust or pumice and round magnetic particles, about $\frac{1}{500}$ of an inch in diameter. They resemble similar larger particles from deep-sea deposits at the greatest distance from continental land. None are of cosmic origin. Usually they have a small nucleus in the interior, but they are frequently hollow. Further observations are to be made at various stations, all over the world.—*Nature, Oct. 1, 1885.*

RAPID TRANSIT AND ELEVATED RAILROADS, WITH A DESCRIPTION OF THE MEIGS ELEVATED RAILWAY SYSTEM.*

BY FRANCIS E. GALLOUPE, M. E., BOSTON, MASS.

[*Concluded from Volume CXXI, page 220.*]

DISCUSSION.

MR. DURFEE.—I would like to ask the author of the paper a question that occurred to me while he was reading it—whether those diagonal wheels are sustaining wheels or steadying wheels. The exterior diameter of the wheel is considerably larger than the diameter of the bottom of its groove, and, it seems to me, there must be a grinding action there.

MR. GALLOUPE—The diagonal wheels are the sustaining or supporting wheels for the weight. We do not suppose that that grinding action will be any worse than the present flange friction upon the ordinary wheel; but it can be entirely prevented by using the ordinary form of rail placed at the proper angle and changing the shape of the wheels to wheels having a flat tread with or without flanges at the sides.

MR. DURFEE.—It seems to me that the grinding action there must be very destructive both to wheel and track. It would bring a very awkward strain on the inner flange of each wheel.

MR. KENT.—I did not notice any suggestion in the paper regarding the influence of wind strains. We know how the Tay Bridge fell down, because it did not have a wide enough base.

MR. GALLOUPE.—All these questions have been carefully considered and gone over. It has been studied for some five or six years both by civil engineers as well as mechanical engineers, and strain sheets made with every modification of the track structure, and besides the calculations of theory, tests by model were made so far as practicable. The whole system is now being built of full size, experimentally, with about one-half a mile of track containing the most extreme conditions as to grades and curves

*A paper read at the Boston meeting, 1884, of the Amer. Soc. Mechanical Engineers, and reprinted from advance sheets of the *Transactions*.

and difficulties, which will ever be likely to occur in practice, and it is to be tested practically to see whether the theories will be upheld. All these things have been considered, and the maximum strains that can be brought on the way and on every part of the system have been taken in designing it.

Mr. Halsey.—I am not a railroad man, but I see one point in the design which appears to be very objectionable—the switch shown on page 147. In principle this is substantially the old-fashioned stub switch, the dangers of which are so great, even on surface lines of track, that in the State of New York I believe its

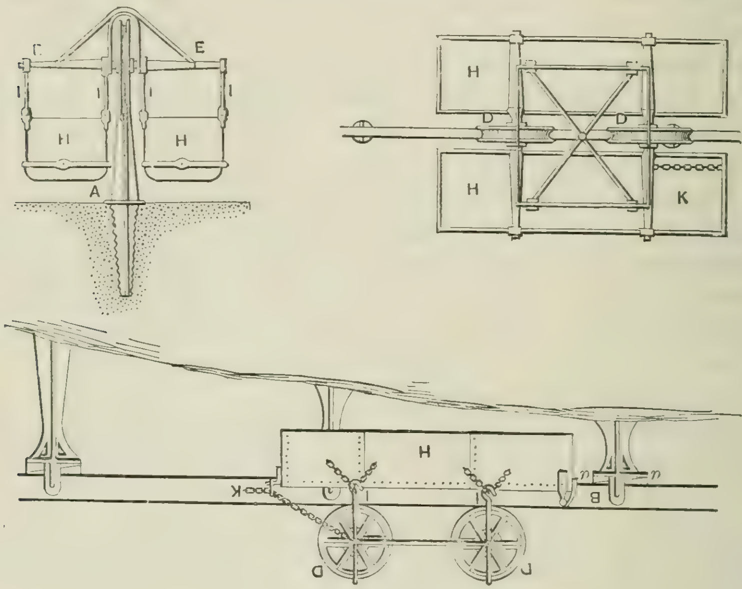


Fig. 110.

use is now prohibited by law. It does not seem possible with a track constructed on this plan to apply any of the modern safety switches. As the result of a misplaced switch of the construction shown, might be to run a train off the end of the track and drop it bodily into the street, the objection seems to me a serious—perhaps a fatal—one.

Mr. Durfee.—The idea of supporting a train of moving cars upon a single rail supported by girders sustained by posts, is a very old one indeed. In the year 1824, five years before the opening of the Liverpool and Manchester Railway, Henry R. Palmer,

civil engineer, published a "Description of a Railway on a New Principle,"* which consisted of a single track supported on posts. The wheels and trucks were above the roof of the cars, which were suspended from the trucks like panniers, on each side of the track (*Fig. 110*). The centre of gravity in that construction was very much lower than in the one under consideration. One of the illustrations of Mr. Palmer's book (reproduced in *Fig. 111*) is of especial interest, as showing an early form of the cantilever bridge. The form of single rail, post-supported track described by Mr. Palmer, has been several times before the public since the publication of his book. In the year 1834, Henry Sargent, of Boston, built at Chelsea a circular railway (intended for amusement only) on this plan, and commenced the construc-

FIG. 111.

* Description of a railway on a new principle, with observations on those hitherto constructed, and a table showing the comparative amount of resistance on several now in use. Also an illustration of a newly-observed fact relating to the friction of axles, and a description of an improved dynamometer for ascertaining the resistance of floating vessels and carriages moving on roads and railways. By Henry R. Palmer, Civil Engineer, Member of the Institution of Civil Engineers. With plates. Second edition, revised. London: Printed for J. Taylor, at the Architectural Library, High Holborn, 1824.

tion of a larger structure in East Boston, on a location described as "a marshy piece of ground, full of creeks and ponds, and much more unfavorable than the average surface of the country." At the Centennial Exposition, there was a short section of single rail on posts, on which ran a peculiar locomotive, having a passenger car attached Other examples of similar attempts might be given. I fail to detect any conspicuous novelty in the car body described; substantially the

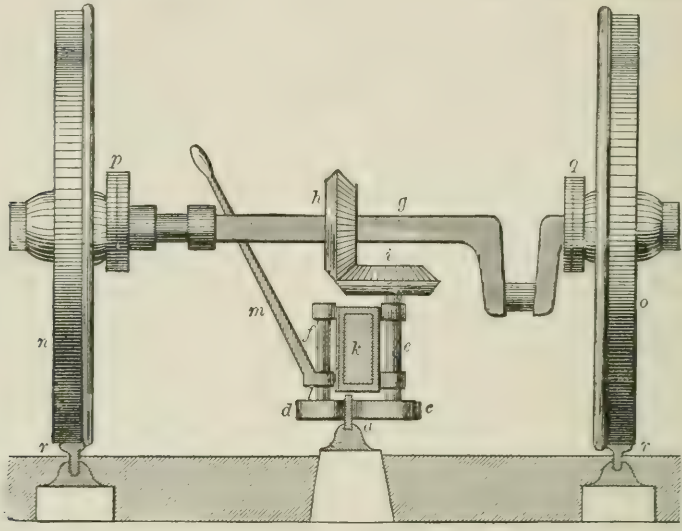


FIG. 112.

same construction was proposed by a Mr. Robbins, and an illustrated description thereof published many years since. The plan proposed to insure tractive power by means of a pair of horizontal gripping wheels, was originally devised by Vignoles and Ericsson (*Fig. 112*), and an English patent granted therefor in 1830, and it has been patented several times since both in England and the United States. It was used on the Mont Cenis Railway, but was not regarded as a decided success.

PROF HUTTON.—There is one thing to which I look forward with interest, and that is to see how they will manage one of the details of the switch. If it is desirable to have the switch move over a very small angle it would seem as if it were necessary that a very long girder should be used to be swung at its heel in order that the permanent way of the siding may clear the permanent way

of the main track. I know that that has been one very great difficulty in railways constructed on this principle heretofore.

Mr. Schuhmann.—During the Centennial Exhibition there was shown a short elevated railroad, and that had the rail in the middle and the wheels on top of the car. The car itself hung down, saddle fashion, on both sides of the rail, as in the form illustrated by Mr. Durfee.

The President.—Was the power contained within the car?

Mr. Schuhmann.—I believe it was; I do not remember exactly. The road was only about 150 feet long. They used to take passengers on it for five cents. It ran across Lansdowne Ravine in Fairmount Park.

ADDED SINCE THE MEETING.

Mr. Galloupe —In answer to Mr. Durfee's remark that a slipping or grinding action of the truck wheels would bring a strain upon the inner flanges of the wheels, I would say that it was particularly intended to show in the paper, under the discussion of the truck's action, that such a thing could not occur, as demonstrated both by theory and actual trials with models. The stresses must de distributed on both flanges or sides of the truck wheels equally, or they will move upon their axles (since there is nothing to resist motion in contact with the hubs, and the position of the wheels is entirely governed by the rails) until this occurs. This has always been found a difficult point to establish, but will I think become clear upon a little reflection. It is one of those cases where seeing, rather than trusting to theory, is believing.

In regard to Mr. Halsey's comment upon the switch, I would say that it is difficult to judge of a thing involving so many new conditions by the analogies of the surface railroads. We have here no very small rail section or switch points, invisible to the engine driver beyond a few feet away, and hence necessary to have the protection of a safety frog, but in this case a large girder 2 feet wide by 4 feet in depth comprising the switch section, its position being easily seen for a much greater distance, and hence largely increasing instead of diminishing the safety of this feature. Besides that, while the ordinary switch points have to be moved not more than an inch or two out of place to derail a train this switch may be moved *fifteen* inches out of place with no effect

resulting from a train running upon it in this position except to close it, an action following from the form and inclination of the truck wheels striking it.

The present safety switch system in use on surface railroads embodies the features of a continuous bearing for the supporting wheels, and this is by no means impossible in the Meigs system. It would involve the use of a girder of double the usual depth, and divided into two parts horizontally. The supporting wheels would run on the upper boom of the lower member, and this would be continuous except that it would have frogs. The upper member would be the one to be swung to connect the branch tracks and main line. The details of this safety switch have been worked out so far as to demonstrate that it is fully feasible, but in particulars, will depend largely in any instance on the details of girder selected, and on the maximum and minimum headway required or allowed by local authorities beneath the girder.

There is also a device to be soon applied to it that will hold the switch in one position or the other, as by springs, either open or closed, so that I do not see that the switch is more unsafe than the ordinary one, but quite the contrary. The great desideratum is to prevent derailment, a thing which the ordinary switch is not too perfect in accomplishing.

Prof. Hutton's suggestion that a small switch angle would necessitate a very long girder for the switch is undoubtedly true, but this truck will never require an inclination of switch section to main line greater than about 5°, and is moreover perfectly adapted to turning angles, not requiring a small switch angle, on account of its independently rotating supporting wheels, and the central position of the upper wheels about which the truck turns. With the above inclination, the length of switch truss will be moderate, not exceeding thirty-five feet.

As to the Robbins car, the only feature in common with it and the Meigs is that it is round, the method and weight of the framing and construction being dissimilar throughout. I believe they were both designed about the same time.

I am obliged to Mr. Durfee for alluding to the history of elevated or post-line railroads. The earliest proposer of a single post line railway, of which I know, in England is Henry Robinson Palmer, whose patent is dated November 22, 1821. He shows a

FIG. 140.– Fisher, 1825.

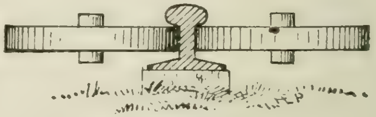


FIG. 141.—Newton, 1845.

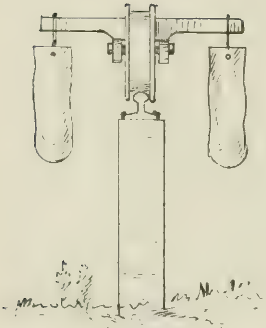


FIG. 139.—Palmer, 1821.

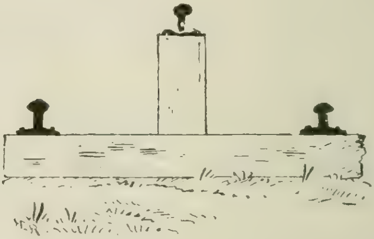


FIG. 142.—Clinton, 1846.

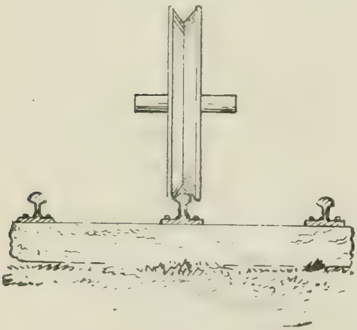


FIG. 143.—Brown; 1846.

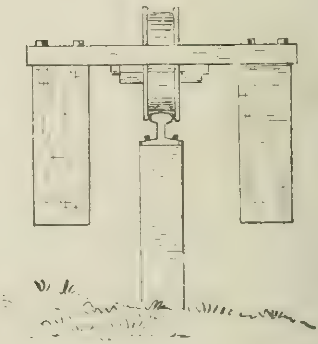


FIG. 144.—Sargeant, 1825.

(*Galloupe.*)

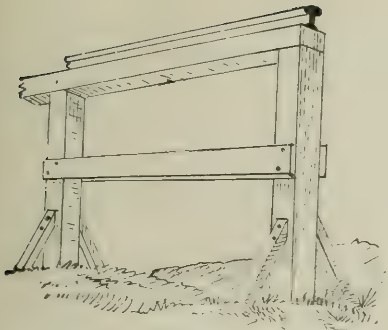


FIG. 145.—Stimpson, 1830.

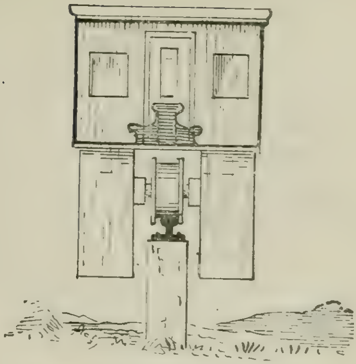


FIG. 146.—Bryant and Hyett, 1831.

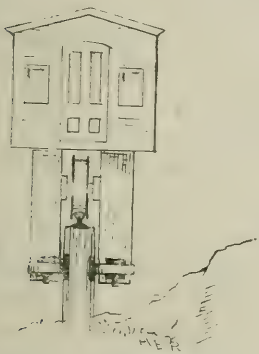


FIG. 147.—Emmons, 1837.

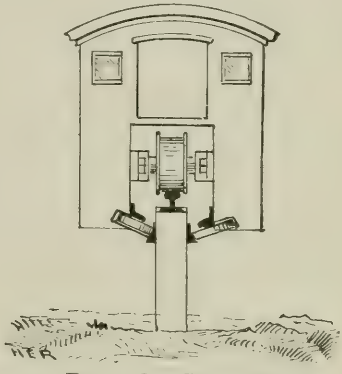


FIG. 148.—Crew, 1872.

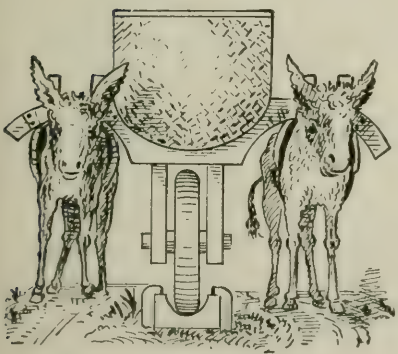


FIG. 149.—Cameron, 1878.

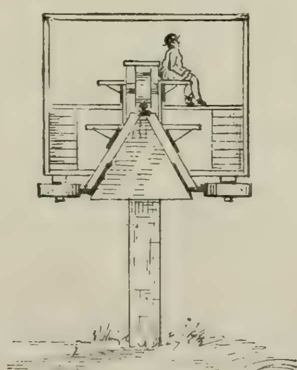


FIG. 150.—Stone, 1876.

beam carrying a single rail on top and supported upon a line of posts. Upon this rail runs a vertical supporting wheel for the load, which in this case consists of bags carried one on each side, like panniers. (Described in *Rep. of Arts*, Vol. I, 3d series, p. 129; *Newton's London Journal*, Vol. V, p. 151, Vol. X, p. 32: *Mechanics' Magazine*, Vol. XXVII, p. 349; *Register Arts and Sciences*, Vol. I, pp. 97, 131; Vol. II, pp. 150, 353; Vol. III, p. 141; Vol. IV, p. 219; Vol. I, new series, p. 9; Vol. IV, p. 25; *Engineers' and Mechanics' Encyclopædia*, Vol. I, p. 615; Vol. II, p. 425.]

Since then probably over 100 different patents have been taken out in England and the United States in this line, of which I will briefly refer only to the following:

Among the English patents, April 2, 1825, a patent was taken out by Jacob Jedden Fisher for a suspended railway, in which weights were shown suspended below the level of the rail on each side, the track itself being supported like the floor of a suspension bridge.

D. Maxwell, May 10, 1829, had a patent on suspended cars.

William Newton, an English attorney, took out a patent July 30, 1845, upon a rail of ordinary section, having horizontal wheels running upon its sides, close to the ground. Another was that of Robertson J. Clinton, June 4, 1846, who provided a central rail between the two ordinary rails, and elevated this rail to a higher position.

July 14, 1846, Sir Samuel Brown took out a patent on a central rail and a wheel having a notched or groove to run upon it.

In the United States, we have Henry Sargeant, May 6, 1825, who patented a post-line railway carrying a rail on top and vertical supporting wheels carrying panniers of wood, upon each side. He printed a pamphlet upon it, which was published in Boston, April 30, 1827.

J. Stimpson, June 3, 1830, also patented a single post-line wooden way, having side strips upon the posts.

In the patent of Bryant and Hyett, June 13, 1831, a vertical wheel is shown on a post-line railroad, with the load supported by it hanging down on each side of the posts. A similar patent is J. Richards', patented March 9, 1832.

But the nearest approach to the method adopted in the system under consideration was that by U. Emmons, in the United States,

April 17, 1837, who, in addition to the post line, single rail and wheel on top carrying the car pannier-fashion, and which extended down upon each side of the posts, employed side rails upon the posts upon which run horizontal steadying wheels for the lower part of the car.

July 2, 1872, a patent by E. Crew shows inclined steadying wheels.

To conclude this brief review of these crude and disconnected ideas but two more need be named.

The "Cameron" Pontoon Cart, proposed for South Africa, may be regarded as the simplest possible form for a railway. It consisted in fastening to the ground by rough, notched sticks a line of hollow logs cut lengthwise in halves, not unlike a wooden house-gutter in appearance. In this groove was a single wheel carrying a basket with arms on each side. This "wheel-barrow principle," as it is called, required the equilibrium to be maintained and propelling power furnished by men or animals. Also log railroads have been used, one by Richardson Brothers, at a mill near Truckee, Nev.

This conception, elevated on posts about three feet from the ground, was an idea suggested by J. L. Haddam, Engineer-in-Chief of the Ottoman Government, for a military railroad, and a section was built, with engine and rolling stock, the latter being in form like an inverted V, or on the "camel saddle" principle, hanging upon each side.

The single-rail railroad, so-called, built at the Philadelphia Exhibition in 1876, over Belmont Ravine, was invented by Gen. Le Roy Stone, of New York. It was elevated about thirty-five feet and was about 500 feet long, really consisting of *three* rails instead of one, the section being not unlike the letter A, with a rail at each angle of the triangle. The supporting rail was at the top, the lower rails carrying the horizontal steadying wheels for the saddle-bag car. It was previously built at Phœnixville, Pa. The engine was a rotary one of the La France pattern and connected direct to the supporting wheels by gears instead of cranks. One fatal objection to it seems to be its inability to turn curves.

Thus, while some of the ideas mentioned above undoubtedly enter as elements in the system under consideration, it cannot be said that any of them resemble it closely. It is a fact that this

plan existed previous to the designing of the New York system, and was offered at the time the latter had been determined upon. Generally speaking, the differences from any previous ideas proposed are that it is a truck system like the ordinary railway system, and as such adapted to turning curves with facility. Then, it is *not* a single rail system, but has four rails instead of one, two or three, and the supporting wheels for the load are the lowest instead of the highest rails where more than one is employed. It also has four supporting wheels for each truck, or the same number as the ordinary railroad, which was not the case in the previous plans.

These early ideas were not practical; they had no truck system, and nobody would put in money to develop the practical details. As in the case of the telephone and other great improvements, it is the man who can develop the crude ideas, put them in practical form in all their details, and who creates a new and useful appliance by a new application of principles, though they be very old, who is entitled to the larger share of credit? In considering a railroad, unlike a machine which may be complete in itself, we must have a *system*, which is complete. Previous attempts have failed, because the system necessary could not be carried out without meeting objections fatal to success. Besides, so far as appears, but few of those mentioned ever advanced beyond the conception stage to anything like a practical working.

APPENDIX III.

RAPID TRANSIT AND ELEVATED RAILROADS.

PROOF OF ACTION OF FORCES ON THE MEIGS WHEELS.—In *Fig. 139* let $a\ G$ be the vertical force due to gravity acting downward upon the wheels and guides. We may separate this central force into two vertical and parallel forces $b\ w$, $b\ w$, whose point of application is at the central point of junction of the axles and wheels. Now, the force $b\ w$ may be resolved into the two forces of which it is the resultant, $b\ s$ and $s\ w$, at right angles. $S\ w$, at right angles to the axle $a\ s$, tends only to transmit a pressure through the centre line of the wheel, or normal to the rail at c.

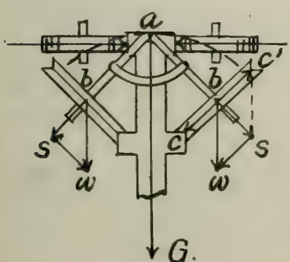


FIG. 139.

If we consider the axles produced until they meet at a as a rigid frame, being

so constructed in the truck frame as to be immovable, two motions only are possible. (1.) A rotary motion of the point *a* in an arc passing through *a*, in which case the arms *a s* would slide through the wheels, which motion is prevented with the least supporting force by the position of the two balancing wheels pressing horizontally at the point *a*, or exactly opposite to the tangential force which would cause rotation. (2.) Since the angle cannot rotate, the effect of the load producing the force *b s* tends to crowd the axles through the wheels and to increase or spread the angle *s a s*, the direction of the force being *b c'*. Since this is balanced by a rigid resistance presented by the truck frame itself, its reaction is equal and opposite to the stress caused by the force *a s*, and produces a pressure, *b c*, also normal to the axle and rail at *c*, or directly through the centre of the wheel.

Therefore, the wheel runs as freely in the inclined position as if it were running over a horizontal surface, and would do the same if it had a flat tread parallel to the axle, and without flanges or hub bearings, when it would lack only a guide.

To supply this, either hub bearings must be provided, which are inadmissible, to prevent the wheel from moving out of position, up or down upon the axle, or light flanges to keep it upon the rail. The wheel itself rolls as freely as any wheel rolls over a plane surface. Neither flange in a flat tread-wheel would bear any portion of the load (except the small load due to the weight of the wheel itself, which, of course, acts vertically downward upon the upper flange), but only serves to guide the wheel in position.

Since the direction of all loads on the car is the same as the force of gravity acting on the trucks' weight, the action will be the same for all, light or heavy loads, equally. F. E. G.

OZONE FROM PLANTS.—Dr. J. M. Anders, in connection with Dr. G. B. M. Miller, has been continuing his experiments in plant transpiration, and in the *American Naturalist*, for September, contributes a paper upon the exhalation of ozone by odorous plants. The conclusions reached by his experiments are as follows: (1.) Flowering plants, including odorous and inodorous, generate ozone, the former, however, much more actively than the latter. (2.) So far as tested, scented foliage possesses the power to produce ozone, and in the case of pine or hemlock foliage in marked degree. (3.) Inasmuch as no reactions occurred on rainy days, it is highly probable that the function demands the influence of the sun's rays, or, at least, good diffused light.—*Botan. Gazette, Sept. and Oct., 1885.*

MECHANICAL APPLIANCES IN TOWN SEWERAGE.

By Geo. E. Waring, Jr.

[*A Lecture delivered before the* Franklin Institute, *January 18, 1886.*]

The general subject of town sewerage has been much discussed during these later years, and the importance of the adoption of some efficient measure for the removal beyond the limits of a town, while still in a fresh condition, of all those manifold wastes of human life and industry which are capable of being transported in running water, is well known. All this part of the subject is far better understood now than it was twenty years ago, or even ten years ago. It is hardly necessary to add further argument to the stimulus in this direction, that is so frequently and so sadly furnished by the repeated occurrence of diseases which, formerly ascribed to the act of God, are now well known to be due to the negligence of man.

Perhaps the short time at our disposal this evening may, with advantage, be directed to the consideration of the mechanical appliances of which works of sewerage consist. Until recently we were guided almost entirely by tradition, "rule of thumb," and "common sense."

Let us suppose that at the outset, in a new settlement, a community established itself on both banks of a brook which could be depended on for a supply of water, and for the immediate removal of surface drainage. As the community grew, it resorted to the better source of water to be found at greater or less depth under ground, and the brook become only a drain. When it got to be a nuisance, from its irregular form, and as it became important to make use of the land along its immediate banks, its sides were walled. For the convenience of traffic, roads crossing it were bridged. In time it was found necessary, as a matter of convenience and to get rid of its unsightly appearance, to cover it over. Little by little neighboring houses discharged their wastes into it, generally under restrictions against the introduction o fœcal matter, based upon the erroneous notion, so long prevalent that fœcal matter was the only seriously offensive waste discharged from houses. Often this covered brook, now become a covered common sewer, remained for generations in that condition. Indeed

such drains still exist in our oldest and largest cities, notably, one in Broad Street, New York, in the heart of the Wall Street district, which is still the only outlet of the drainage of a considerable population, but concerning the condition of which we have only traditional knowledge.

Very often water courses existing under the condition above depicted are not merely walled and covered over; their place is taken by large mason-work conduits constituting a greater or less improvement on the ruder device.

This is the origin, and this the type, of town sewerage as generally known in this country and elsewhere. The sewers of Paris had a similar origin and perform a similar office. Some of the larger ones among them, the only ones that the public is allowed to inspect, are applied to the further use of furnishing channels for water pipes, electric wires, etc. They were formerly used for gas pipes as well, but explosions due to leakage of gas made it necessary to abandon this use.

Pretty nearly the whole of London is sewered on a similar system, and, as London and Paris are established authorities and trusted examples of municipal work, the system has extended elsewhere. The considerable use of large pipes as a substitute for brick conduits in London, and subsequently in other English towns, has furnished an example which has been followed here and abroad.

The sewer of antiquity, even of comparatively recent times and in by far the majority of cases to this day, is constructed in a more or less modified form on the theory that it must remove surface wash from streets, the outflow from industrial establishments and the wastes of houses.

Nearly forty years ago the idea was advanced in England that there would be a sanitary and economical advantage in separating street water—an uncertain and constantly-changing quantity—from the more regular flow of industrial and domestic wastes. This was the origin of the separate system of sewerage. Though then, and still, called by this name, the separation in English work has been only partial. It has been decided by the courts there that a house-owner cannot be compelled to make two drains from his premises. He is, therefore, allowed to discharge the rain water falling on his yard and on his roofs into the public sewer. This has the

advantage—more important there than here, because of the much greater frequency with which it rains—of affording a certain irregular flushing to remove deposits from the sewers. It has the disadvantage—much less there than here, because of the infrequency of torrential rains in England—that it requires the sewers to be constructed of an unduly large size as compared with what would be necessary for the immediate purpose of removing foul wastes The English separate system, which is in many respects a great improvement over that formerly prevalent in that country, has been proved by long experience to be reasonably well adapted to the conditions by which its use is regulated.

The argument in favor of this separate system is a strong one. Large storm water sewers, however well they may be flushed during storms, are very liable to the formation of deposits during dry weather, because the mere thread of a stream that they ordinarily carry is not sufficient to prevent the retention of organic matters which, during their retention, undergo putrefaction and give off objectionable gases. The admission of street wastes increases very much the amount of deposit, and, while matters coming from the street are less offensive under putrefaction than are ordinary household wastes, they are often bulky and heavy, and constitute a nucleus for the retention and accumulation of fœcal matter, and other putrescible substances which, without their presence, would have a better chance to be washed away in the flow. Owing to their much larger size, these storm water sewers are more costly than the smaller separate sewers. As the ventilation of sewers, as generally constructed, is extremely imperfect, they often contain a confined atmosphere which, on the sudden increase of the volume of water during storms, is forced past the protecting traps into the street and into houses. Viewed merely as a channel for the discharge of water which would do harm if not properly removed, the storm water sewer, as now made, leaves little to be desired. As a channel for the removal of foul matters, it is, as a rule, completely effective only during heavy storms. Perhaps the worst charge that can be brought against the system is the extreme offensiveness of the contained air of such sewers. Any one who has had experience as I have had in the inspection of works of this character, cannot fail to have observed the almost absolute uniformity with which their atmosphere is contaminated by the products of putrefaction.

Another serious objection to storm water sewers has been developed by the modern requirement which is imperative, in so many cases, to make some other disposition of their flow than its simple delivery into a river or harbor, or into the sea. There are a few favored localities, but they are very few, where such disposal is final and unobjectionable. The necessity is already realized in many places, and is fast being realized in others, either to extend and improve the outlet by pumping, or to purify the effluent more or less completely by mechanical precipitation, or by agricultural irrigation. If sewerage is to be pumped, it is important as a measure of economy to reduce the amount to be so handled as much as possible; to this end, it is desirable that there be excluded from it all water which may without disadvantage be disposed of by natural flow. If the more obviously offensive portions of the sewage are to be removed by mechanical precipitation, it is important that the volume be kept small, and that it be as nearly regular as may be, day by day. If it is to be used as a fertilizer, or is to be purified by distribution over land through which it may be filtered, it is especially important not only that the volume be kept small and regular, but that particularly during rainy weather, when the land is least capable of receiving it, its volume be not inordinately increased by adding to it mere surface flow which might find another and relatively inoffensive outlet.

It is quite usual now, where storm water sewers are used, to make provision for the disposal of the increased flow during storms by means of relief overflows. This would serve a very good purpose if the storm water would be obliging enough to flow on top of the foul sewage, escaping at the overflow in a reasonably pure condition. Unfortunately, the whole mass becomes thoroughly mixed; the foul flow is greatly diluted, and the overflowing excess is greatly contaminated. This is the most serious objection to the relief-overflow system, but there is another which, though generally lost sight of, is by no means unimportant. The overflow weir must be fixed at a certain height; unless it is so high that it will surely retain in the main sewer the maximum flow of an average day, which occupies ordinarily but a very short time in the forenoon, some of this maximum flow will escape daily at the overflow outlet. If, to provide against this, the overflow weir is placed somewhat above any possible elevation of dry weather flow, then

even a very light, continuous rain, will increase the daily discharge at the main outlet to very many times the volume due to house drainage alone.

Where the English separate system is used, supposing the same restrictive requirements to obtain, a similar method of relief overflows must necessarily be adopted, producing the same difficulties, though perhaps in somewhat less degree.

Another serious disadvantage, which has been recognized only within a few years past, and which applies in even greater degree to the smaller English separate system than to the storm water system, is due to the enormous amount of air carried into a sewer by the rapid flow of roof water down the leader pipes. This flow attains great velocity and force. It never occupies anything like the full bore of the leader, except during very heavy storms, and at or near the top. In its descent it carries forward, with force, a great amount of air; this air, entering the sewer, becomes impounded and accumulates under such pressure as to force a final relief, often with great power. Instances have been cited where sewage driven back through a house drain, has spirted up through a kitchen sink with such force as to strike and besmear the ceiling; and where iron man-hole covers, luted somewhat securely into their position with dirt, have, on giving way under the increasing pressure, been blown high into the air. These effects and similar ones, even the perceptible blowing of air through the traps of fixtures in a house, are often due to the air carried in under accumulating pressure through roof leaders, and, to less degree, through street inlet basins.

It is this effect of air-compression, added to the inadequacy of sizes, which may be sufficient in England, to cope with our violent rain bursts, which makes that system so unsuited for this country.

If we assume that the systems above described are for any good reason necessary, and that relief from their disadvantages is to be gained by ingenious mechanical appliances, then we must confess that modern effort has been skilful and effective in giving relief.

Some works with which I have myself had the good fortune to be connected would seem to indicate that relief is to be secured rather by avoidance and prevention than by remedy.

Long impressed with the great disproportion between the sizes

of sewers and the work that they had to do during at least ninety-five per cent. of the time, I had an opportunity to test the actual dry weather requirements, by gaugings made in a number of cities in different parts of the country. The result was conclusive, and was all in one direction. Among other records is that of a large sewer in Milwaukee, furnishing the only means of outlet for a population of 3,177, having a very slight fall, and having the initial velocity of its flow arrested during the trial by a dam built across it. In this dam an ordinary six-inch sewer pipe was inserted. The greatest depth of flow during the forenoon of washing day—the greatest flow of the week—reached in this pipe a depth of only five and one-half inches.

Based on these demonstrations, I laid out a system for the sewerage of Memphis, in which the size of all lateral sewers not more than 2,000 feet in length was restricted to six inches. There are now about forty miles of sewers on this system in Memphis, and of these more than eighty per cent. are only six inches in diameter. Unless accidentally obstructed, not one of these six-inch sewers has ever been known to run half-full; many of them, too, are laid on moderate grades. The success of this work has led to the construction of sewers of the same diameter in Omaha, Pullman, Ill., Kalamazoo, Little Rock, Leavenworth, Birmingham, Ala., Norfolk, Pittsfield, and Chelsea, Mass , Keene, N. H., and on a small scale in other places. A large experimental system on the same plan has been working constantly in one of the worst quarters of Paris for more than two years.

If no other result had been accomplished by this work, it is much to have had it so universally demonstrated under such variety of conditions, that a six-inch sewer is fully adequate to the performance of the duty ordinarily imposed, so far as house drainage is concerned, on very much larger ones,—sewers costing more to construct, more difficult to ventilate, and much more difficult to keep clean.

In other words, considering a tube as the chief mechanical appliance for town sewerage, we have learned, so far as the removal of filth is concerned, that it will be greatly cheapened and improved by having its size reduced nearly to a minimum.

We have learned by this part of the work that the simple function of carrying a stream of sewage produced by a considerable population may be performed by a six-inch tube.

If we consider some of the mechanical adjuncts of the Memphis work, we find that an equal improvement has been effected in the condition of the contained air of the sewer. A large tube, receiving liquid and solid matters, has, at least during the upper part of its course, too shallow a current of liquid to carry all of the solids forward; some of these are inevitably stranded by the way, other solids being gradually added to them, and all of the conditions favoring putrefaction. Putrefaction in a sewer is like putrefaction in a cesspool; it produces offensive and pernicious gases; it probably develops the growth of dangerous micro-organisms, and it produces, as the sum of its results, that dangerous compound of stench and infection called "sewer gas."

In the storm water sewer, as has already been hinted, the accumulation of deposits is favored by the introduction of rubbish from the streets. In the English separate sewers, the accumulation is considerable, because of the considerable radius necessarily given to the channel. In both cases, theoretically at least, each storm introduces a sufficient amount of water to wash these accumulations away; and in the best of such conditions during a storm the sewer is thoroughly cleansed. Unfortunately, no sooner does the rain cease than deposit and accumulation begin again, producing after a few days the former objectionable condition. So uniform has been this result that to most persons the word "sewer" necessarily implies "sewer gas," and it is one of the most difficult tasks of the sanitarian to show that the supposed cause can exist without the assumed effect.

As sewers were universally built before the Memphis work was done, the assumption was correct. There was introduced there, however, another condition which entirely altered the state of affairs. Having, because of the inadequacy of such small sewers to carry rain water, deprived them of even the occasional flushing that rain water would afford, it became necessary to adopt other means of cleansing.

For this purpose there was placed at the upper end of every branch of the whole system a small brick reservoir, built under the street, with a capacity of about two hogsheads, fed by a trickling stream from the water supply, and provided with an automatic siphon by which, when the tank was filled and began to overflow, the whole volume was rapidly discharged into the head of the sewer,

assuring it a thoroughly cleansing current throughout all of its upper portion, where the natural stream is never strong enough at any time during the day to remove all that is delivered into it.

The source of foul air was thus very largely, but not with absolute completeness, removed; there remained still to be guarded against the smearing of the walls of the sewer which, without ventilation, would of itself be sufficient to produce a very foul condition of the small amount of air that such sewers hold. The only means for obviating this difficulty seemed to be to secure a most copious ventilation, much more copious than would be possible with the large sewers of the combined system.

The persistence of certain habits of thought has been curiously illustrated by those who have discussed the ventilation of the Memphis sewers on the basis of systems of ventilation applicable to large sewers. Even so distinguished a man as Professor Baumeister has declared that, as air moves more freely through large channels than through small ones, therefore the ventilation of the Memphis sewers must necessarily be less effective than would be that of larger sewers with the same means of inlet and outlet, and with the same frictional forces acting upon it. He, and numerous others who have agreed with him, have disregarded the important consideration that, in order to make this reasoning correct, they should have given to the large sewer the same *proportional* means of inlet and outlet, and the same *proportional* effect of friction. For example: Take a six-inch sewer carrying a stream two inches deep, with a given velocity, having a length of 200 feet, and having eight occupied houses on each side of the way. Suppose these houses to be provided, as in Memphis, with untrapped four-inch house drains and soil-pipes opening into the sewer above the water-line and delivering above the roof with an open mouth. Under such conditions we have in this 200 feet of sewer about thirty-three cubic feet of air subject to the inward and outward currents due to sixteen four-inch pipes, having a combined sectional area of about 200 square inches. The area of surface of a stream flowing two inches deep in a six-inch sewer 200 feet long is about ninety square feet. As the stream flows, it produces a frictional effect on the volume of air above it, which, in order to renew the whole atmosphere of the sewer, has to impart its movement to only thirty-three cubic feet of air.

Let us now suppose the sewer to be three feet in diameter and to carry the same volume of water. The flow, having much less hydraulic mean depth, will have less velocity, probably enough to counterbalance its increased area in contact with the air, so that it will be fair to ascribe to it the same influence in moving the contained volume, but that volume is now increased from thirty-three cubic feet to 1,414 cubic feet. As a much greater area of the wall of the sewer will be covered and laid dry with fluctuations in the flow, the amount of smearing will be greater and the amount of contamination will be in proportion. This will, in part if not entirely, make up for the greater dilution which the larger volume affords; so that if we consider only the effect of the stream we see that the purification of the contained air can by no means be so great.

In the case of the six-inch sewer, the proportion between the square feet of ventilating area furnished by the sixteen house-drains and the cubic feet of contained air, was as one to twenty-five (about); in the case of the three-foot sewer it is as one to over 1,000. Assuming, as we safely may, that the force applied in the case of the six-inch sewer is very much greater than is needed for the purification of the six-inch pipe, we see that purification is practically complete; and observation in the case of all six-inch sewers constructed on the Memphis system, of which I have had knowledge, shows, not a comparative but a complete absence of the peculiar odor of organic putrefaction. That is to say, in such sewers "sewer gas" does not exist, and the fear engendered by the present almost universal condition of town sewers becomes entirely unfounded.

In addition to the effect of ventilation through house drains and of the friction of the stream ordinary flowing, a sudden greatly increased effect is produced by the discharge of the flush tanks. These send through the sewer such a volume of water, flowing at such high velocity, that practically all of the air in advance of the wave is driven forward with force and sent out through the house drains as they are successively reached, the partial vacuum following the wave being supplied by a sudden indraft through those which have been passed.

Incidentally to the discussion of the Memphis system, it is appropriate to speak of another of the mechanical appliances of

sewerage known as the manhole. The manhole is a well, built from the sewer to the surface of the street and there properly covered, through which access is obtained to the channel for observation and for cleansing. Guided, as we are all guided, by fixed traditions, I planned to construct manholes at regular short intervals over the whole work. When the estimates came to be made, it was found that the total cost of construction would be more than the community was able to pay; something had to be cut down. It seemed that the safest thing to dispense with would be the manhole on the small lateral sewers. This effected a very great saving and, with the help of a restriction of the size of the main sewer to what was necessary for present purposes, the total cost was brought within the prescribed limits.

Curiously, the chief criticism that has been made on the system here adopted related to the absence of manholes—which was not a part of the system at all. The subsequent modification of the work to which the abandoning of manholes led, was the introduction of handholes at short intervals. It was found that when obstructions occurred, and they were very easily located by their effect on house drains, it was necessary to break through the top of the pipe to remove them. The openings thus made could not be satisfactorily closed. There was then introduced, in the further work, a pipe having an opening at its top and a moulded cap of the same material to fit it. The location of these caps being known, it was always easy to get access to the sewer within not more than fifty feet of an obstruction. Later, some of these openings were covered with caps having branches into which six-inch pipes were inserted, the standpipe being carried up to within about two feet of the surface of the ground. This greatly facilitated the work of inspection, the street being little disturbed by excavating to this slighter depth. These appliances have been effective and have now become a regularly adopted feature of the system wherever applied.

Owing to obstructions due to special causes, there have been built in Memphis six manholes on six-inch sewers; on one lateral within a length of 700 feet, there are four manholes, and on another there are two manholes 300 feet apart; these are the only ones on about 180,000 feet of six-inch sewer, being an "average" of one to about five or six miles. So far as I have been able to learn, there

is no disposition to build more. At the same time, but for the cost of the work it would unquestionably be an improvement to build frequent manholes leading *to* but not *in*to the pipe. Such small sewers are so easily obstructed that an opportunity should not be given to throw into them things which it may be desired to conceal. The sewer pipe should be exposed at the bottom of the manhole, but entrance to it should be through a handhole with a well secured cover.

As a substitute for manholes, handholes and standpipes, a recent improvement is worth consideration. It is the invention of Burton R. Phillipson, of Dublin. He introduces at intervals a branch with a funnel-shaped junction with the sewer, so as to afford no occasion for floating objects to lodge, and he continues this with an inclined pipe nearly to the surface of the ground, covering it there with a special casting, taking the place of the ordinary manhole cover and easily opened for inspection of the sewer. As this pipe inclines toward the axis of the sewer and has a rounded connection with it, a stout telegraph wire, which is after all the best device for inspection or for cleansing, can be inserted, in the absence of angles, for a distance of several hundred feet. Incidentally to this arrangement, Mr. Phillipson has invented a very ingenious device for cleansing the sewer or damming back water for special flushing effect in case of need. He uses a soft india-rubber ball, or elongated bag, capable of being expanded to rather more than the full size of the sewer; to this an air pipe is connected; it is inserted into the sewer a little below the branch, and is then blown up until it makes a tight fit; the pressure of water accumulating behind it only makes it fit the tighter and in this way sewage may be dammed back to the surface of the street. Any partial obstruction higher up the stream may then be driven from its attachment by the forcible working of a plunger in the vertical column of water, imparting the shock to the contents of the sewer above. When the proper flushing volume has accumulated, the opening of the air valve will speedily release the rubber plug which may be drawn out, allowing the whole volume to flow forward.

Still following the traditions, the public, many of our boards of health, and not a few of our engineers, still insist that whatever else is done and whatever other safeguards are provided, the drainage works of the house must be absolutely shut off from any

form of connection with the atmosphere of the sewer by a trap on the main drain.

It would be out of place here to enter into a full discussion of the subject, but it seems pertinent to observe that this is another case where prevention is better than remedy; and that, disregarding all other bearings of the case, if the universal ventilation of the sewer through house drains will secure the abolition, or the very great mitigation, of the sewer gas difficulty, it is better to accomplish this in this way than to allow the dreaded demon to exist, as he surely will in the absence of such ventilation, and then try to keep him out of the house by the interposition of a few quarts of water.

It is also to be said that all communication between the house itself and the pipe through which its wastes are discharged must be shut off by traps at all fixtures, which shall be absolutely reliable under all circumstances. This being done, even very foul air coming from the sewer will pass out through the open soil-pipe, rather than pursue a tortuous and obstructed course through small branches into our rooms.

A cardinal element of the system used at Memphis is the automatic flush-tank, already referred to, placed at the head of each branch sewer of the whole system. It is quite important that whatever device may be used for flushing the sewers should be arranged to work automatically and with certainty. It not only costs inordinately, in money and in water, to flush sewers by hand through their manholes, but the performance of an essential duty like this, the neglect of which, even for forty-eight hours, would establish a foul condition in the sewers, depending on personal attention, and on the direction and control of the average underpaid and overworked city official, cannot be relied on.

Automatic flush-tanks are of various sorts and kinds. Perhaps the oldest and most familiar is the tumbler-tank, which becomes overloaded on its discharging side when nearly full, and then tips and spills, dropping back to its former position after it has been emptied. This tank is costly, for its joints and bearings must be rust-proof; its balance and counterpoise must be nicely adjusted, and, however carefully it may be made, it is pretty sure, sooner or later, to get stuck up or down, or more often at the half-way point, and to refuse to act.

There have been many recent inventions of flush-tanks, some of them very ingenious, and some of them very good and practical. The only one that has come to my notice which seems to be absolutely unobjectionable is what is known as Rogers Field's tank. Mr. Field is a skilful and careful engineer, who has long made a specialty in England of works of sanitary drainage. The siphon by which this tank is discharged has been with him a plant of slow growth, and its ultimate perfection was the result of a long series of experiments. It has the very great advantage—one might almost say, considering the importance of having everything connected with a system of sewerage so adjusted that it will take care of itself, the indispensable advantage—that it is entirely without moving parts. It is practically as simple as a mill dam. Some minor modifications of form have been made in this country, as the result of experience and of observation, but the original principle remains precisely as Mr. Field devised it. Its peculiarity is confined entirely to the discharging limb, and it makes practically no difference whether its form be a bend, or what is known as an annular siphon. Let us consider the annular form:

A reservoir of a certain size is provided with a standpipe, passing through its bottom and having its top at the level to which it is desired to fill the tank. This standpipe, for a tank of ordinary size, is four inches in diameter. Its lower end under the tank is not connected directly with the head of the sewer, but delivers into a basin, which, when filled to its overflow point, holds water just in contact with the lower end of the standpipe, sealing it, but not sealing it to any considerable depth. The upper end of the standpipe is provided with an adjutage, or funnel, from which the falling water drops clear of the sides of the pipe, and falls directly into the water in the lower chamber. As it falls it carries bubbles of air with it. Some of these bubbles rise again into the standpipe, but some are driven beyond its edge and rise into the chamber outside of the pipe. So long as this remains an uncovered standpipe, this process might go on forever without withdrawing more water from the tank than would naturally overflow at its top.

Let us now take a dome, or a larger pipe, say eight inches in diameter, tightly closed at the top, and pass it down over the standpipe so as to leave a space between the two for the whole

circumference. This space now becomes the receiving limb of a siphon, and, if siphonic action is once established, it will continue to run until the level of the water in the tank is carried down to the bottom of the outside pipe and air is taken in. There is nothing novel in the annular form of siphon.

What takes place in Field's siphon is this: The top of the standpipe being sealed by the water contained between it and the outer pipe and the lower end being sealed by contact with water in the discharging chamber, we have, at the moment when the overflow begins, a certain volume of confined air at natural atmospheric pressure. A small stream overflowing and dropping from the adjutage to the water below, carrying air bubbles down as described, and some of these bubbles escaping outside of the foot of the standpipe, there is a gradual removal of the air; the pressure is reduced, water rises a little into the lower end of the pipe and the rapidity of overflow is proportionately increased. The increased flow carries out more air, and after a few moments' operation—longer or shorter according to the volume of the stream added to the reservoir—so much is removed, and the falling stream is so much increased that the remaining air is soon discharged, and the siphon works with a solid stream.

In Memphis, the tanks have a discharging capacity of 120 gallons—about two hogsheads. If accurately adjusted, a stream barely large enough to fill the tank once in twenty-four hours is enough, after it is filled and begins to overflow, to bring the siphon into action within from five to ten minutes, and the entire volume is discharged, in some cases in as little as thirty-five seconds.

It was found that while the siphon could be brought into action as described, something further was needed to make its breaking complete; that is, to get rid of all of the water contained in the siphon itself after the first checking of the flow by the first intake of air. This could best be done from below. It is accomplished by the operation of what is called a subsidiary siphon. This, in its simplest form, is a pipe carried from the discharging chamber over its elevated overflow point and down into the outlet. While the main volume is being discharged, a part of it passes through this pipe, which continues to act as a siphon after the flow through the main siphon has ceased. Its further supply of water comes from the outlet chamber at the foot of the standpipe, the level of whose water

is thus reduced below the lower end of the standpipe which, becoming unsealed, loses its entire charge, the contents of the receiving limb dropping back into the tank, and the contents of the discharging limb falling into the chamber and passing off through the subsidiary siphon.

The water of the subsidiary siphon having been lowered an inch or more below the mouth of the standpipe, a new discharge of the tank cannot be set up until it has been refilled and the overflow has continued sufficiently long to fill the outlet chamber again and thus reseal the lower end of the discharging limb.

It has been found in practice that a small pipe adequate to the emptying of the discharging chamber is subject to stoppage from the accumulation of rubbish of one sort or another before its inlet. This difficulty was obviated by using a diaphragm in the main discharge which, while not materially reducing the capacity of the outlet, gave a subsidiary siphon of sufficiently large area to carry off foreign matters without choking.

Then another difficulty arose. The outlet of the subsidiary siphon being so large, air was taken back through it and its action was stopped before the desired effect was accomplished. To cover this difficulty a block or dam is placed in the outlet in front of the subsidiary siphon, holding back the flow to such an extent as to prevent the admission of air until the work of emptying the outlet chamber is done.

Still another difficulty was found in practice: As the standpipe or discharging limb was originally made, it was but little larger than the mouth of the adjutage or funnel. Blisters of rust accumulating on the inside of the pipe sometimes projected so far out as to catch the falling stream and lead it down into the outlet chamber along the side of the pipe without carrying out the air. To remedy this, the pipe was made considerably larger, increasing the space between the edge of the funnel and its outer wall, and then drawn in at the bottom so that the water should fall very near to its side and allow a larger proportion of the air bubbles to escape outside.

These modifications and some improvements in construction not necessary to describe here having been made, the siphon is now absolutely and permanently effective. It is simple in construction and may be depended on to perform its offices year after year with absolute certainty. It may be, of course, that the ingenuity that

is constantly applied to the subject will result in producing some other form of automatic device that will be even cheaper and better than this; but thus far nothing has been produced at all comparable with it.

There is a good field for invention, and much need for it, in the matter of outlet, especially for the drainage of low-lying districts and of town areas which, while they may have sufficient fall to low water mark, have their outflow obstructed twice a day by the rise of the tide.

One of the most ingenious things that has been devised in this connection is what is known as Shone's ejector, somewhat used in England, and now contemplated for application at Sacramento. This is a sort of self-acting compressed air pump, controlled by automatic valves operated by floats. A tight reservoir of any convenient size is built in the ground at the lowest point of the district it is to serve, and to this the sewage of the whole district is led. Its outlet communicates with a force main; its air vent is open and its outlet is closed. The sewage flows into it, and when it is filled, operates floats, which close the air vent and admit the pressure by which the contents are driven through the force main. This system of pumping is especially applicable to towns having numerous depressed points in no easy communication with each other, or for very large, wide areas where sufficient fall cannot be obtained without a depth of cutting that would be very costly in unstable soils. Its chief drawback relates to the loss of power in compressing air, which is serious; and to its moving valves.

Generally it would be cheaper, maintenance considered, to lay one large, low main sewer, by tunnel if necessary, to carry the out-fall level back with little loss for fall, or to do the pumping all at one central station, applying the power directly to the pump rather than to use it for the compression of air.

Perhaps, too, the same end may be accomplished by the direct application of power at as many different points as may be necessary, by means of gas engines. These are about being used for the pumping of the whole sewage flow of the borough of Stamford, Conn., and that experiment will give us the information necessary to determine whether or not this power may be economically applied at different points throughout a town.

A case has recently occurred in the carrying out of a plan of my own, in which it was necessary to surmount an unexpected obstacle.

In Norfolk, Va., the entire sewage of the city is discharged into a pumping well, in which the mouth of the suction pipe stands at a point ten and one-half feet below low water mark. The main sewer of a system covering about one-third of the town was to be discharged into this well, and in order to reach branches necessarily laid at about the level of high water in the most distant part of the town, a low grade for the main sewer had to be preserved. It was contemplated to lay for this a pipe sewer eighteen inches in diameter about fifteen feet below the surface for a considerable part of its length. It was soon found that the soil in which it would be necessary to work was an almost impassible quicksand, and there was reason to fear that in passing a very large Masonic temple its foundations would be disturbed by the running of the earth. The scheme had to be abandoned. The sewers for the upper part of the system had already been laid, with the aid of active pumping. In devising the means for relief, I had recourse to a plan I had recommended for the drainage of a town in Holland, but not there put in practice. A well was sunk at the end of the completed main, about 1,700 feet distant from the pumping well, and was carried down several feet below the level of the intake of the pumps, its total depth being about twenty-one feet. Into this, the main sewer delivered. From it, at a point six inches below the sewer inlet, there started a fourteen-inch iron pipe, which was carried up the well and thence along the street, but little below the surface, turning down into the pumping well and being finished with a return bend, which would always remain full of water and would serve as a permanent sealing trap. The overflow of this sealing trap is a few inches higher than the intake at the open well. This constitutes a siphon by which the sewage flowing into the upper well is carried upward about thirteen feet and then forward into the pump well. As sewage rises in the upper well, it flows out at the mouth of the siphon, the head required for its discharge being practically what is due to the theoretical flow through a fourteen-inch pipe 1,700 feet long of the discharge of an eighteen-inch pipe, which will rarely, if ever, run half full. This siphon has now been working for some seven months, and it is

said by the city engineer to be an entire success. It was charged by a pump attached to the main steam pumps and connected with the apex by a two-inch iron pipe. This pump is operated for a few minutes every day to remove accumulated air.

Had I not recently had occasion to read a paper in this city on the disposal of sewage, including the destruction or utilization of its wastes, I should have regarded that subject as constituting a better compliance with the invitation of your Professor of Chemistry. The proper applications of the mechanical appliances used for the removal of the waste of population, need, however, to be well understood even by students who give their attention chiefly to the chemical problem connected with disposal and utilization.

CONSTRUCTION OF A LARGE PRONY BRAKE.

By Prof. R. H. Thurston.

In planning the investigation made by Messrs. Gately and Kletzsch, of which an account appeared in the Journal of the Franklin Institute, of October last,* it was first necessary to secure some means of controlling the velocity of the engine with certainty and safety, at the highest speeds and greatest power that it could be expected would be attained. The usual method was obviously the best for the purpose, and the design of a Prony brake thus formed a part of the problem to be attacked by the investigators.

The form of brake finally concluded upon was substantially the same as that used previously by several well-known engineers. It consists of a brake wheel, or pulley, which is keyed on the engine-shaft, and is sufficiently strong to sustain safely the maximum load anticipated. The rim of this pulley is turned flat and very smooth, and is fitted with a flexible brake-strap of wrought iron, or other suitable material, which may be adjusted to such a tension as will enable it to control the engine at maximum power.

The rim is trough-shaped in section, flanges extending inward toward the shaft to a sufficient depth to permit the retention in the circular trough so formed of a stream of water which is used to keep the pulley cool, and to carry away the heat produced by transformation of mechanical energy.

---

* Journal Franklin Institute, October, November, December, 1885; *London Engineer*, November, December, 1885.

The two ends of the brake-strap are united by a right and left hand screw, in such manner that they may be drawn together and the strap set up to any desired degree of tension. The brake-arms consist of two beams, of wood, forming an < frame, and secured to the strap at the upper and lower sides, and at their junction supported by a strut resting on a platform scale of nice construction and great accuracy. As the engine-shaft revolves, the tendency of the brake-arms to turn is resisted by the scale, and the effort so measured, multiplied by the relative velocity of the engine-shaft and the supported point on the arm, gives a measure of the power expended.

Water is supplied to the pulley-rim, by means of a hose, from any convenient source, and the excess is taken away in a similar manner. The centrifugal action of the rotating mass keeps the fluid in place in the pulley-rim, and the eduction pipe receives the water carried away by it as the tender of a locomotive scoops water from between the tracks, when at high speed. This system of cooling permits efficient lubrication, without admixture of the grease with the water, and secures a perfection of smoothness and uniformity of rubbing surfaces unattainable with the older forms of brake.

The following is an account, in detail, of the designing and proportioning of the brake, as reported to the writer by the gentlemen who so well performed the work. The brake, when constructed, was found to have a very satisfactory form, and worked well under higher loads than the writer had ever before known to be controlled by this means. So far as he was aware, no successful attempt had ever been made to control so powerful an engine with the Prony brake. The smooth action of the turbine better adapts that motor to this system of management, and Mr. S. Webber has used the brake, in that field, at higher powers; but the irregular action of the steam pressure in the modern steam engine introduces difficulties of serious magnitude, when it is attempted to thus handle its constantly varying efforts.

DESCRIPTION.

The brake described below was designed to control a Harris-Corliss engine at Sandy Hook, Conn. It is a modification of the well-known Prony brake, described in Rankine's "Machinery and Mill Work," page 383, § 341. It was designed for the maximum

power of the engine, *i. e.*, taking steam at full stroke, the engine running at 100 pounds pressure, and at 100 revolutions per minute. The diameter of the cylinder being 18 inches and the stroke 42 inches, we have for the maximum power developed:

$$HP = \frac{254{\cdot}47 \times 100 \times 42 \times 2 \times 100}{33000} = 540{\cdot} +$$

The brake was accordingly designed to control the engine when exerting this power, and to be used upon a 5-foot pulley of 24-inch face. The size of the pulley was chosen of this diameter, rather than larger, simply because it compelled less removal of floor and railings about the engine, and would also lessen the cost of construction of the pulley.

Having assumed the diameter of the pulley upon which the brake-strap was to be used, the calculations for the remaining parts of the controlling apparatus is as follows:

Assumed diameter, 5 feet; assumed maximum speed of engine, 100 revolutions; circumference, 15·708 feet. This would give for the greatest linear velocity of the pulley per minute, 1570·8 feet. Dividing the greatest number of foot pounds developed by the engine, at its maximum speed and pressure, by the linear velocity, gives the resistance at the rim of the pulley; or,

$$\frac{540 \times 33000}{1570{\cdot}8} = 11{,}345 \text{ pounds;}$$

which figure is the total friction, in pounds, on the face of the pulley.

BRAKE–BLOCKS.

The blocks used in constructing the brake were 2½ inches thick, 5 inches wide, and 24 inches long, of unseasoned white oak. In order to keep the brake upon the face of the pulley, wooden lugs were attached to the ends of the blocks, which were placed 7 inches from centre to centre, thus leaving a space of 2 inches between adjacent blocks, for diffusion of the heat and lubrication of the pulley. The blocks were attached to the flexible brake-straps by means of wrought iron lag-screws of ¼ inch section, and 2¼ inches in length. The three blocks at the top of the pulley were fastened to the arms of the brake, and were of seasoned birch, as no white oak of the size of these blocks was to be had in the neighborhood.

SIZE OF FLEXIBLE BANDS.

The straps, two in number, were calculated according to Rankine ("Machinery and Mill Work," § 354, page 403).

Let T_1 and T_2 represent the tensions at the ends of the band which embraces the pulley, and let T_1 be the maximum tension.

Then T_1 exceeds the tension, T_2 by an amount equal to the friction between the blocks and the pulley; *i. e.*,

$$R = T_1 - T_2 = 11.345.$$

Let c denote the ratio which the arc of contact bears to the circumference of the pulley, f the coefficient of friction between the blocks and the pulley; then the ratio $T_1 : T_2$ is the number whose common logarithm is $2{\cdot}7288\ cf$; or,

$$\frac{T_1}{T_2} = 10^{2{\cdot}7288\,fc} = N.$$

c, the arc of contact of the bands $= 1$, and f, the coefficient of friction between wood and cast iron (well lubricated) was taken at $0{\cdot}2$; then

$$N = 10^{2{\cdot}7288\,fc} = 10^{2{\cdot}7288 \times {\cdot}2 \times 1};$$

or,

$$\frac{T_1}{T_2} = 10^{0{\cdot}54576} = 3{\cdot}5.$$

Having found $R = 11{,}345$ pounds, we have for the greatest tension on the band,

$$T_1 = R\frac{N}{N - 1};$$

and substituting the values of R and N in this equation, we have

$$T_1 = 11{,}345\,\frac{3{\cdot}5}{3{\cdot}5 - 1} = 15{,}883 \text{ pounds.}$$

Hence, for the combined tension on the band, and, using two straps, we have for the tension on one,

$$\frac{15{,}883}{2} = 7941{\cdot}5 \text{ pounds.}$$

Taking the tensile strength of such wrought iron, as given by authorities, at 40,000 pounds per square inch, and allowing for a six-fold factor of safety, we obtain for the section of the band,

$$\frac{\text{pull} \times \text{factor of safety}}{\text{tensile strength}} = \text{section in square inch};$$

or,

$$\frac{7941 \cdot 5 \times 6}{40{,}000} = 1 \cdot 19 \text{ square inches.}$$

The nearest band-iron of this section was $\frac{3}{8}$ x 3 inches, and, after careful testing, it was found to be of sufficient strength; thus giving, at the same time, the required flexibility, which is of vital importance in the operation of brakes. At each end of the bands, it was found necessary to weld on round bar-iron, to admit of threads being cut for the purpose of tightening and loosening the brake.

As this bar-iron is subjected to the same stress as the bands, the section should be the same; hence, we have for the section of belt:

$$\pi r^2 = 1 \cdot 19;$$
$$r = \cdot 625;$$

and the diameter should be 1·25 inches. These bars were of unequal length, being purposely so made in order to permit the passing of the angle-iron of the one used in tightening and taking up the wear of the brake. The bands passed through the arms of the brakes and thence through the angle-iron, which was made specially for this purpose, and placed above the arms. This angle-iron was not rigidly attached to the brake; it was held firmly in place by the tightening of the bands and also by means of dove-tailed wedges which were driven home, occasionally, in order to prevent any moving should they have been loosened in any way by the continual tremor of the brake.

ARMS.

The arms were two in number, of 6 x 6 inches of well-seasoned spruce. The length was made 10 feet 6 1 inches from centre of the bearing surface on the pulley to centre of bearing surface on the scale.

This length was purposely so chosen, as it, in the first place, brought the scale beyond the rim of the fly wheel, and, secondly, it greatly facilitates calculations of the horse-power developed—the circumference of a circle, whose radius is 10 feet 6·1 inches, being 66 feet. Thus instead of multiplying by 66 feet, and then

dividing by 33,000 to obtain the horse-power, it is only necessary to divide the product of the net scale pressure and the revolutions per minute by 550, the quotient being the horse-power developed, *i. e.*:

$$HP = \frac{W \times Rev. \times 66}{33{,}000} = \frac{W \times Rev.}{550}$$

The arms were but slightly tapered, so as to get as much weight as possible at the ends, without encumbering the apparatus, and in order to produce a greater stability, and consequently a more uniform running of the engine.

The ends of the arms were connected by a piece of chestnut 2 x 8 x 18 inches, firmly bolted to them, the bolts being turned conical at the ends, and of the same length, so as to insure a uniform bearing on the scale. This was also further adjustable by the wrought-iron ties connected with the bands on the under side of the brake; and, by means of a swivel placed in each tie, these could be tightened or loosened accordingly as one or the other of the bolts were found not to be bearing firmly.

The stand through which the pressure was transmitted to the scale was composed of two uprights, 6 x 6 inches, of white pine, surmounting a pedestal covering the greater part of the scale platform. Upon these uprights was placed a steel plate of ¾-inch thickness, which received the pressure of the bolts. The scale was a "Fairbank's Standard," was carefully balanced, and was capable of accurately weighing 3,000 pounds. All weights used were carefully weighed on a standard balance, and none were used that were found not to be absolutely correct.

THE PULLEY.

It was found necessary to design and construct a special pulley upon which the brake could be used when the maximum power of the engine was being developed. The design and calculation was an important matter, as upon the strength of this pulley depended the safety of the engine and of those assisting in the experiments. Besides, several factors entered in its construction which we have noticed before; as, for instance, the heating and expanding of the rim and arms caused by the friction of the brake; the great normal pressure caused by the tightening of the brake, and the unequal pressure the rim would be subjected to in tightening first one band and then the other.

As already mentioned, it was deemed advisable to make the pulley 5 feet in diameter. In order to clear both the fly wheel and eccentric, it was found necessary to make the pulley of 24-inch face.

As the common segmental arm would give but a very narrow bearing for the rim, the writer advised an arm of T-section, which was found to answer the purpose.

The calculations for the parts of the pulley were made according to Unwin, ("Machine Design"), who gives for the thickness of rim:

$$t = 0{\cdot}7\ \delta + 0{\cdot}005\ D$$

where D = diameter in inches = 60 inches;

and δ = thickness of belt taken at 0·5 inches.

Hence, by substitution,

$$t = 0{\cdot}7 \times {\cdot}5 \quad 0{\cdot}005 \times 60;$$
$$= 0{\cdot}65 \text{ inch.}$$

The number of arms was assumed at *6;* and from the same author, for the thickness at the nave,

$$h = 0{\cdot}1781 \sqrt[3]{\frac{P\ D}{n}}$$

P being the driving effort, 11,345 pounds;

D = diameter = 60 inches; and

n = number of arms = 6;

$$h = 0{\cdot}1781 \sqrt[3]{\frac{11{,}345 \times 60}{6}};$$
$$h = 8{\cdot}54 \text{ inches.}$$

h_2 = breadth of arms = $\frac{h}{2}$ = 4·27 inches.

For h at the rim, we take ⅔ that of the nave.

For h_2 at the rim we take ⅔ that of the nave.

For the thickness of the nave,

$$\delta = 0{\cdot}18 \sqrt[3]{B\ D} - \tfrac{1}{4};$$

where B is the face = 24 inches;

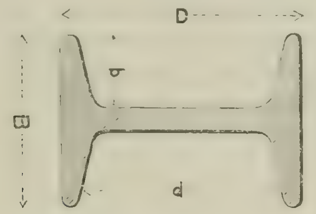
D is the diameter = 60 inches.

Substituting, we have

$$\therefore \quad \delta = 0{\cdot}18 \sqrt[3]{24 \times 60} + \tfrac{1}{4}$$
$$\delta = 2{\cdot}1 \text{ inches.}$$

The diameter of the main shaft being 9·12 inches, the calculated thickness of the nave was judged rather small, and 2·5 was used instead. The rim was also made 1/8 inch heavier at the centre than the calculated dimension used for the edges of the rim.

CALCULATIONS FOR DOUBLE T ARM.



From Trautwine, page 196, we find for the moment of inertia of this section,

$$I = \tfrac{1}{12}\, B\, D^3 - \tfrac{1}{12}\,(2\, b d^3)$$

and, considering the arm as fixed at one end and loaded at the other (Wood's "Resistance of Materials," Eq. (182) page 188),

$$P l = \frac{R\, I}{d}$$

where $P =$ load;
$l =$ length of arm;
$I =$ moment of inertia;
$R =$ modulus of rupture;
$d = \tfrac{1}{2}\, D.$

Load on 1 arm $= \tfrac{1}{6}$ of $15{,}600 = 2600 = P.$
$l = 30 - 7\tfrac{1}{2} = 22{\cdot}5$ inches.
$I = \tfrac{1}{12}(4 \times 8^3) - \tfrac{1}{12}(2 \times 1\tfrac{1}{4} \times 5^3) = 40{\cdot}6.$

Allowing a factor of safety of 3, we have by substituting in the above formula, and transposing,

$$3 \times 2600 \times 22\tfrac{1}{2} = \frac{R \times 40{\cdot}6}{4};$$
$$175500 = R \times 10{\cdot}15;$$
$$R = 17{,}290;$$

hence, the above sections and dimensions are ample.

MANIPULATING THE BRAKE.

The controlling of the engine by means of the brake needed the attention of one man, and was not an easy task. For the purpose of handling the brake with ease, a platform was placed at a

convenient height, and, by means of a long wrench, the tightening and loosening of the bands was easily accomplished. On account of the heating and consequent expansion of the face of the pulley when dry, the friction was increased and caused an unnecessary fluctuation in the speed. To prevent this heating, water was led to the inner face of the pulley from the mill-dam through a 2½ inch fire-hose. By this means, the face of the pulley was kept quite cool, and, as the friction between the brake-blocks and the face of the pulley was reduced to a minimum by effective lubrication (beef tallow, fine flake plumbago, and lard oil were found to work best), the constancy of the conditions under which the test was made was well maintained.

On the whole, this design was considered by the writer one of the best, and its operation one of the most successful illustrations of the application of Prony's invention that he had ever met with; and it has been thought that this detailed account of its design and construction may prove interesting to many others in the profession.

DIRECTOR'S ROOMS, SIBLEY COLLEGE,
CORNELL UNIVERSITY, *Ithaca, N. Y., January, 1886.*

SUMMARY OF ENGINEERING AND INDUSTRIAL PROGRESS FOR THE YEAR 1885.

[*From the Report of the Secretary made at the Stated Meeting, held Wednesday, February 17, 1886.*]

THE PREDICTION, respecting the outlook for the year 1885, which I ventured in the introductory paragraph of last year's summary has been literally fulfilled. This prediction was conveyed in the words "there are signs, however, to indicate that the year we are just entering upon will witness a marked improvement in the industrial situation."

The past year witnessed the removal of several of the most formidable obstacles in the path of prosperity, and a very general revival of industrial and commercial activity: and it closed with these favorable conditions still dominating the situation, and with the general prevalence of a feeling of confidence that the country had left behind it the stagnation and depression of the past few years, and had fairly entered upon a new era of prosperity. The

belief in the settlement of the acrimonious warfare between the great trunk lines of railway which had brought them, and numbers of less important lines, to the verge of bankruptcy, and the restoration of rates for freight and passenger service to a paying basis, were undoubtedly the principal factors in bringing about the improvement in general business which characterized the later months of the past year.

A REVIEW of the iron trade, exhibits the fact that the depression of the previous two years continued until about the middle of 1885, when symptoms of a revival became manifest. The improvement from that time forth, and down to the present, has been uninterrupted, and the feeling among the manufacturers is one of confidence. The steel makers have thus far reaped the lion's share of benefit from this revival of activity, but the other branches of the trade have at length begun also to experience its vivifying influence.

The production of all kinds of pig iron in the United States in 1885, is given by Mr. Swank, of the American Iron and Steel Association, as 4,529,869 net tons, or 4,044,526 gross tons. In 1884, the production was 4,589,613 net tons, or 4,097,868 gross tons. The decrease in 1885 as compared with 1884 was only 59,744 net tons, or 53,342 gross tons.

The reports show that nearly every State and district shared in the increased activity of the second half of the year, and the *Bulletin* says: "As compared with recent years, commencing with the boom year, 1880, the production of pig iron in 1885 presents an exceedingly favorable showing when the depression in all branches of business in the greater part of 1885 is considered."

The production, classified according to the character of the fuel used, as compared with the two preceding years, was given as follows:

	1883.	1884.	1885
Bituminous, ...	2,689,650	2,544,742	2,675,635
Anthracite, ...	1,885,596	1,586,453	1,454,390
Charcoal, ...	571,726	458,418	399,844
Total fuel used, . .	5,146,972	4,589,613	4,529,869

The stocks of unsold pig iron in the hands of the manufacturers or their agents at the close of 1885, and which were not required for

the consumption of those who produced it, amounted to 416,512 net tons, or 371,886 gross tons, not more than half of which was charcoal pig iron. At the close of 1884, the stocks amounted to 593,000 net tons.

The total number of furnaces in blast at the end of 1885 was 276; out of blast, 315, a total of 591. In 1884, 236 in blast, 433 out, a total of 669. The number of new furnaces in course of erection in 1885 was twenty-four.

These figures exhibit the fact that a large percentage of our blast furnaces is still idle, and that the productive capacity of the country is largely in excess of the present demands. The same statement will hold good also of steel. The full capacity of our Bessemer works is approximately 2,000,000 tons per year, while the present production—prudently regulated by agreement among the manufacturers—is at the rate of 1,000,000 tons. The immediate danger that threatens to check the incipient prosperity that has come to our iron industry, is that some sudden and unexpected increase in the demand in excess of the ability of the active works to supply, may tempt the manufacturers to run up prices to considerably higher figures, and thus cause the starting into operation of a large number of idle furnaces and mills, the output of which would speedily glut the market and cause a disastrous fall in prices. The harmonious understanding among the Bessemer works may prevent any such calamity to this branch of the trade, but the furnace and mill men have no such safeguard.

Mr. Swank notes that in Europe the iron trade exhibited no symptoms of revival during the year 1885, the situation of the iron trade there, being worse at the close of the year than it was six months before. The extent of the depression in England will best be told in the following extract from a review of the British iron trade, in (London) *Iron*, viz.:

"The year 1885, * * * * came in with an inherited flutter of hope of better things than it had just left behind it, which hope, however, remained unfulfilled to its close. * * * * When the history of the iron trade during the last quarter of the nineteenth century comes to be written, 1885 will figure as one of the worst, if not the very worst, years of the twenty-five. At the close of 1884 we hoped, almost against hope, that the ensuing year would bring with it better times for all engaged in the iron trade.

We are free to admit that the actual result has fallen very far short indeed of any such consummation, and that, bad as trade was in 1884, it was greatly worse last year."

The Association has just published the complete statistics of the production of Bessemer steel in the United States in 1885, of which the following is a summary:

The production of Bessemer steel ingots in 1885 was 1,701,757 net tons, or 1,519,426 gross tons, an increase of 161,162 net tons over the production in 1884. The production of 1885 was the largest the country ever made. In the following table it is given in comparison with that of the three preceding years.

States.	Net Tons.			
	1882.	1883.	1884.	1885.
Pennsylvania,	933,631	1,044,396	1,031,484	1,109,034
Illinois	397,436	273,325	339,068	366,659
Other States,	365,383	336,906	170,043	226,064
Total,	1,696,450	1,654,627	1,540,595	1,701,757

Pennsylvania made sixty-five per cent. of all the ingots produced in 1885, Illinois made twenty-two per cent., and other States made thirteen per cent. In 1884, Pennsylvania's share was sixty-seven per cent., that of Illinois was twenty-two per cent., and that of other States was eleven per cent. Included in the production of ingots in 1885 were 21,647 net tons of Clapp-Griffiths ingots, which were made by Oliver Brothers & Phillips, at Pittsburgh. This product was made from April 3d to the close of the year. No other Clapp-Griffiths plant was in operation in the United States in 1885. In 1886, there will be several in operation.

The production of Bessemer steel rails in the United States in 1885 was 1,074,607 net tons, or 959,470 gross tons, a decrease of 42,014 net tons on the production of 1884. The production of 1885 was less than in any year since 1880, when it was 954,460 net tons. In the following table, is given the production of Bessemer steel rails in this country from 1881 to 1885.

States.	Net Tons.				
	1881.	1882.	1883	1884.	1885.
Pennsylvania,	688,276	759,524	819,544	763,223	736,522
Illinois,	346,272	336,122	231,355	290,185	308,242
Other States,	295,754	342,509	235,655	63,213	29,843
Total,	1,330,302	1,438,155	1,286,554	1,116,621	1,074,607

The figures of the output of coal during the past year will exhibit no substantial change from those of the year 1884, when about 98,000,000 tons were mined, of which approximately 31,000,000 tons were anthracite, and 67,000,000 tons bituminous and other varieties. The output of 1885, will probably be found slightly to exceed 100,000,000 tons.

From the best available sources of information, the number of miles of new railroad built during the year 1885, was 3,028, as compared with 3,950 miles built in 1884, a decrease of 922 miles, or nearly twenty-five per cent. The total railway mileage of the United States at the close of the year 1885, was 128,970 miles. The most notable event in railway construction during the past year, was the completion of the Canadian Pacific Railroad—a trans-continental line, which, it is expected, will materially aid in developing the resources of the Dominion.

The following table exhibits the number of miles built in each year, and the total mileage of the railways of the United States for a series of years:

	1878.	*1879.*	*1880.*	*1881.*	*1882.*	*1883.*	*1884.*	*1885.*
Number of miles built,	2,916	4,570	7,174	9,789	11,596	6,573	4,350	3,028
Total mileage,	81,774	86,497	97,454	103,242	114,838	121,592	125,942	128,970

The developments of the past year in relation to the progress of the interoceanic canal at Panama, have been decidedly unfavorable. Although, as usual, much of the news from this quarter was contradictory, the following statements respecting the actual condition of the enterprise, and its prospects may be accepted as substantially correct; namely; that the technical difficulties of constructing tidal basins at the termini (for which it appears no provision had been made in the original scheme), and of damming the Chagres River at Gamboa, have been greatly underestimated; that the

amount of excavation required in the gigantic cut at Culebra has likewise been underestimated by at least 20,000,000 cubic meters; that less than one-tenth of the work is yet completed; and that, finally, the original estimates of the cost of the canal ($120,000,000) by Lesseps and his colleagues have been found to be utterly inadequate, and will require to be greatly increased. It is believed that the actual expenditure thus far has exceeded $120,000,000—an amount equal to the original estimate of the cost of the entire work, and, to meet the lately developed obstacles above noted, the canal managers early in the past year applied to the French government for permission to contract a further indebtedness of $120,000,000, by the issue of a lottery loan, as was permitted in the last stages of the construction of the Suez canal.

It is understood that the French government has decided to send out an expert commission of engineers to make an exhaustive examination and to report upon the condition of the enterprise, before deciding to lend its encouragement to further expenditures.

The rival project of Capt. Jas. B. Eads, for the construction of a ship-railway across the Isthmus at Tehuantepec, has not been allowed to slumber. It has been very thoroughly discussed, both in respect to its engineering features and its commercial possibilities, before numerous institutions and public bodies. The projector has secured valuable concessions from the Mexican government, and a guarantee, for a period of years, of two per cent. interest on the obligations which the company proposes to issue to secure the funds necessary for the work. It is the intention of the projectors to ask a similar guarantee of three per cent. of the United States government. The claims are made that the interoceanic ship-railway can be constructed for a fraction of the cost of any canal that can be built; that its construction and operation involve no serious difficulties from a technical standpoint; and that the situation of the line would give it incontestible advantages, in respect to the saving of time, over all others.

Considerable progress was made during the past year on the new Croton aqueduct for supplying the city of New York with water sufficient for its present and future requirements. The total length of this structure, from Croton Dam to the Central Park reservoir, will be thirty-three and one-quarter miles; and when finished, it will have, according to estimate, a delivering capacity

of 320,000,000 gallons per day, or 100 gallons per head for a population of 3,200,000—a quantity which will provide an abundance of water for the needs of the city for many years.

On the 24th of October, which is the date of the latest accessible official returns, 22,342 feet of tunnel work had been completed, and the rate of progress was estimated at about one mile per month. It is believed that, barring accidents, the entire work will be finished in three or four years.

The removal of Flood Rock, the greatest of the remaining obstructions to the navigation of the East River, was successfully accomplished on the 11th of October. The work of tunnelling the reef had been continuously prosecuted for ten years, and at an outlay of nearly $1,000,000. To the twenty-six-foot contour the reef is about 1,200 x 625 feet, an area somewhat over six acres. It was honeycombed with about four miles of tunnels. The total amount of rock excavated aggregated 80,166 cubic yards, leaving about 275,000 cubic yards in the roof and pillars. In these there were drilled 13,286 blast holes, five feet apart in the columns and four feet apart in the roof. These averaged nine feet in depth and three inches in diameter. The explosive with which these were charged was a mixture of rackarock and dynamite, in the proportion of eight volumes of the first to one of the last. The total quantity used amounted to 283,000 pounds, all of which was exploded at once by electrical means. The volume of explosive here used exceeded sixfold the greatest charge ever previously fired. The result of the explosion is believed to have been satisfactory, though this cannot be certainly known until the work of clearing away the *débris* is undertaken.

Of foreign engineering works in course of construction, the most important are the great bridges across the Tay and the Forth in Scotland, which are progressing satisfactorily, but will not be completed for some years. The canal across the Isthmus of Corinth, referred to in last year's summary, is being rapidly advanced. The monthly rate of progress is reported to be about 120,000 cubic metres; 1,500 workmen are employed, and the work is reported to be well under way, including the breakwaters at Isthmia and Posidonia, and an iron railway bridge 141 feet above the water surface. The project of a ship canal to connect Man-

chester with Liverpool has received the sanction of Parliament. It contemplates an entrance at Eastham, near Liverpool, on the Cheshire shore of the Mersey, and a terminus at Manchester, enabling ships of the heaviest tonnage to trade direct with the latter city without the delay of trans-shipment or breaking of bulk. Great advantages to the textile industries of Manchester are expected to result from its completion.

It is interesting to note also that the Channel Tunnel project, which was supposed to have received its quietus, is again being discussed, and its projectors, it is believed, will shortly come before the British Parliament for new legislation in its behalf.

A project to construct a ship canal between the North Sea and the Baltic has at length assumed shape, and will shortly be undertaken. It is designed to be available for war and trading vessels of the largest size.

The plans for the widening of the Suez Canal, to facilitate the transit of vessels, have been agreed upon, but the actual undertaking of the work has been unexpectedly delayed.

The prospects for another Alpine Tunnel seem quite favorable. The probable location will be at the Simplon Pass. The (London) *Engineer*, referring to the probability that this work will shortly be undertaken, says that "the existing line from Geneva to Martigni and Brieg will be carried through the mountain to Domo d'Assola, and soon to Pallanza or Stresa, on the Lago Maggiore." The projected Simplon Tunnel will be at a lower level than the other Alpine tunnels, and will be longer, a rough estimate of its length being about twenty kilometres (or twelve and one-half miles), and of its cost, 100,000,000 francs.

I may note the completion of several works of the first importance. The Severn Tunnel, which was begun with the sanction of the British Parliament, in 1872, by the Great Western Railway Company, was finished toward the close of the year 1885, and was formally opened to traffic at the beginning of the year 1886. It affords an uninterrupted railway communication between England and South Wales. Its total length is 7,664 yards, or somewhat over four and one-third miles.

The Mersey Tunnel, connecting Liverpool and Birmingham, is another important engineering enterprise which was finished during the last days of the year 1885. The total length of this work is

four and one-half miles. The tunnel under the river is just one mile in length from shaft to shaft. Both of these works are of the first importance from an engineering and a commercial standpoint. Another enterprise of considerable importance, which was completed during the year, is the ship canal between Cronstadt and St. Petersburg, which was formally opened on the 27th of May last. It is 17 miles in length and 22 feet in depth, with a width of from 180 to 240 feet.

In the field of electricity the past year may record no startling discovery, although substantial advances in certain directions were made.

In the department of telegraphy, the Phelps induction system is undoubtedly the most important invention brought out during the past year. This system renders it possible to telegraph to and from a railway train travelling at the highest speed, and it is reasonable to suppose that when its capabilities shall have been fully developed in practice, it will contribute materially to the safety of railway travel. The Harlem River branch of the New York, New Haven and Hartford Railroad has been equipped with the Phelps apparatus since the early part of the past year, and experts agree in the opinion that its practical working is satisfactory.

The year also witnessed substantial progress in perfecting and introducing the Delany synchronous-multiplex system, the Baltimore and Ohio Telegraph Company having placed New York, Philadelphia and Baltimore in connection by this system. The inventor has likewise made considerable progress in his attempts to adapt the system to the transmission of fac-simile dispatches.

In telephony, there is little of note to record. The promises held out towards the close of 1884, that the year 1885 should witness the introduction of long-distance telephony on an extensive scale, have only been partially fulfilled; nor has any substantial progress been made in placing electric wires under ground, although the question has been very widely discussed. In view of the progress in this direction that has been accomplished in Europe, the backwardness of this country is quite unaccountable. In all the more prominent cities and towns of Europe the underground system for telegraph and telephone lines is in successful operation; extensive underground land lines of telegraph have been operated for years,

and underground lines of 100 miles or more are in telephonic communication with entire success. From these facts, it would appear that we are not keeping abreast of the progress which other countries are making.

In the department of electric lighting, the most noteworthy contribution of the past year was the publication of the results of the tests of the efficiency and life-duration of incandescent lamps, and of the efficiency of dynamo-electric machines, made under the direction of the FRANKLIN INSTITUTE. These tests have been pronounced by very competent authority to be more reliable and complete than anything that has yet appeared in any part of the world in relation to the subject under discussion. They demonstrated that decided improvements have been made in the construction of incandescent lamps by which their efficiency and life-duration have been notably increased; and, in respect to the dynamo-electric machine, that this has reached so high an efficiency that but little margin for improvement remains.

The considerable extension of electric lighting, both arc and incandescent, during the past year, bears testimony to the continued popularity of these systems of illumination. In this connection, no discovery or invention of great importance is to be noted.

The friends of the secondary battery may be somewhat encouraged by the continued success which Mr. Preece, of the British Telegraph Service, claims to have obtained with them, and, in this country, with the work of Mr. E. P. Roberts, at Cheyenne, in distributing light by their use. The *Electrical World* is authority for the statement that Mr. Roberts considerably extended his plant during the year, and demonstrated that, "with intelligent handling, the secondary battery has to-day a commercial value which cannot be gainsaid."

In the electric transmission of power, the progress of the past year was somewhat more positive. Electric motors for railways have been experimentally tested in a number of American cities—New York, Philadelphia, Baltimore, Cleveland, and elsewhere—the trials of the Daft system of electric locomotion on the elevated railways of New York, and in Baltimore, having attracted widespread attention. The New York experiments do not appear to have been followed by any direct results. In Baltimore, however, the Daft system has been in actual operation since September 1,

1885, on one of the suburban lines of surface railroad (the Baltimore and Hampden Railway). This road was originally a horse railway, and is a feeder of one of the principal lines of street railway in that city. It is about two miles long. Two Daft motors are in use, each rated at ten horse-power, and regular hourly trips are made from one terminus to the other. The system is reported to be working satisfactorily. In Cleveland, on the other hand, where the first experimental trials with the electric railway in this country were made, the latest accounts report that the electric system has been abandoned. Worthy of special note, also, are the researches and experiments of Deprez in connection with the subject of the electric transmission of power over long distances. As the result of experimental trials recently carried on at Creil, in France, Deprez asserts that he has succeeded in transmitting forty horse-power over a distance of more than twenty miles, with an efficiency approximating closely to fifty per cent. The prospect which such a result holds out, of advantageously utilizing the almost unlimited supplies of water-power, which can be made available for the purpose in numberless localities, is highly suggestive.

It is, however, in the department of electro-metallurgy that the most signal advance was achieved during the past year. The invention here referred to is that of the Cowles Brothers, of Cleveland, O. These gentlemen have succeeded in constructing a smelting furnace in which the intense heat of the voltaic arc is applied far more efficiently than has heretofore been found possible, and with which they have succeeded in easily effecting the reduction of the most refractory substances. The essential feature of the Cowles system consists in utilizing the well-known intense heating effects obtainable with the electric current to reinforce the reducing action of carbon. They place in a suitably constructed furnace a mixture of granulated ore and carbon, and pass through this the current of a powerful dynamo. The temperature attainable in this furnace—due to the resistance of the carbon fragments—is said to be so high, that such difficultly-fusible metals as platinum and iridium are instantly melted; and the highly refractory compounds of many substances, such as silicium, boron, magnesium, aluminium, etc., which, under ordinary circumstances, are not decomposed by carbon, are readily decomposed and these substances reduced to their elemental state. The technical and commercial

success of this most interesting process seem to be fully assured. It promises to give to the constructive arts a number of new and useful alloys, and, unless all indications are misleading, it will give the world what has long and vainly been sought for—cheap aluminium. Dr T. Sterry Hunt, whose opinion is entitled to the highest respect, and who has had the opportunity of making a personal investigation of the merits of this invention, believes that it marks the beginning of a new era in the metallurgical arts.

In metallurgy, commendable progress has been made in the direction of simplifying the processes and cheapening the cost of producing steel. Four processes of this nature have attracted much attention. These are known, respectively, as the Clapp-Griffiths, the Davy, the Gordon, and the Avesta. They are all outgrowths of the pneumatic, or Bessemer process, the substantial difference residing in the manner of applying the blast or tuyeres.

The Clapp-Griffiths process is the most promising of these processes. Messrs. Oliver Brothers & Phillips, of Pittsburgh, were the first to introduce this process, and their plant has been in constant operation since the spring of 1885. These works comprise two three-ton converters, with necessary accessories, having an estimated capacity of producing 150 tons of ingots in twenty-four hours.

The favorable comments expressed in last year's summary on the importance of the introduction of natural gas in its bearing on the industries of Pittsburgh and vicinity, prove to have been entirely justified. During the past year, the changes which its introduction has brought about, may properly be characterized as a revolution in industrial and domestic economy. It has practically superseded coal for nearly all manufacturing purposes, and has come to be largely used for domestic heating. The difficulties and dangers resulting from the enormous pressures at which the gas issues from the wells have been practically overcome by the adoption of mechanical artifices, by which the pressure in the mains is reduced to a few pounds, and in the service pipes to a few ounces. At present, three important companies control the supplies of natural gas in Pittsburgh and its suburbs—the Philadelphia (Westinghouse) Company, whose pipe system covers Pittsburgh and Alleghany City; the Chartiers Valley Gas Company,

whose service pipes are intended to supply the mills on both sides of the Monongahela River; and the Alleghany Heating Company, which supplies Alleghany City with gas furnished by the first-named company. At last advices, the total mileage of pipes laid is about 600 miles. The pipes range from six to twenty-four inches in diameter. The mains leading from the wells are wrought iron pipes, from ten to sixteen inches in diameter. The lines used through the city are twenty and twenty-four-inch mains, from which a network of six, eight, ten and twelve-inch service lines branches off to supply domestic consumers. The gas piped to the city represents the total product of about fifty wells.

Natural gas is now used in most of the iron, steel, copper, brass and other metal-working establishments; in all the glass factories (about seventy in number); in all the hotels; and is rapidly coming into use for domestic service. The price charged to manufacturers varies according to their consumption, being, in the case of iron and steel, so much per ton of finished product. The number of domestic consumers is rapidly increasing, and, it is estimated that at the close of the year no less than 1,000 dwelling houses were supplied with gaseous fuel. The rate charged for this class of consumers is, in Pittsburgh, a fixed sum per house, and in Alleghany City, ten cents net per 1,000 cubic feet.

The new fuel has been in use long enough to demonstrate that coal can largely be dispensed with in Pittsburgh and vicinity. The amount of coal displaced by gas already exceeds 10,000 tons daily, the equivalent of the output of 2,500 miners. The direct result has been the abandonment of a number of the mines heretofore worked to supply the Pittsburgh market, and a fall of thirty-five to forty per cent. in the price of coal. The superiority of the gaseous fuel over coal, because of its greater purity and the more perfect control of the heats, has been fully demonstrated, and the general result is, not only that a better quality of iron, steel and glass can be made than from coal, but the economy in cost is so marked that the manufacturers of this favored region have decidedly the advantage of their less fortunate competitors away from the gas belt.

Whether or not it will be found practicable to pipe the gas to considerable distances, or even, as has been suggested, as far as the great seaboard cities, is problematical. The question of the

permanence of the supply also is one which is involved in some uncertainty, though on this score but little uneasiness appears to be felt.

The opinion of those best informed seems to be that when once accustomed to gaseous fuel, neither manufacturers nor domestic consumers will willingly return to the use of coal. The future probabilities are well summarized in the following terms by one of the best informed journals: "In case the wells should fail, of which there is no present prospect, it is already settled that some form of fuel-gas will be manufactured to take its place. The Westinghouse Company has had some such contingency in view, and should the wells cease to give their supply, their large pipe lines can be used in the distribution of artificial fuel-gas. Western Pennsylvania has millions upon millions of tons of refuse coal, or 'slack,' which can be manufactured at the mouths of the coal-pits at very small cost, and with proper machinery forced through the pipes to the consumers; or, what is more to the purpose, water-gas can be manufactured and delivered to the consumer at a cost but little in excess of the price now charged for natural gas, the estimated cost being about ten cents per 1,000 feet."

One of the indirect consequences of the introduction of natural gas in the Pittsburgh region, has been to direct attention in other industrial centres to the question of the feasibility of introducing artificial fuel-gas; and it is quite probable that in the near future a number of experiments of this nature will be undertaken. In this connection it may not be amiss to note the fact that the admirable exposition of the capabilities of water-gas made at the Novelties Exhibition of the FRANKLIN INSTITUTE, in Philadelphia, and which, in respect to completeness and variety, far surpassed anything of the kind heretofore attempted, has contributed very materially to the education of public opinion on this important question.

OF considerable technical interest, likewise, is the report of a special committee of the American Society of Civil Engineers, on the subject of the preservation of timber, which was made public last summer. This committee, after a very exhaustive examination of all accessible data, reports very positively in favor of the economy of wood preservation. In Europe, the testimony on this point is

very decided. In this country wood preservation is in the experimental stage, but, in the committee's opinion, the time has arrived when, in many sections, an economy of from twenty to fifty per cent. will result from the preservative treatment of cross-ties and timber structures, while in other sections timber is still too cheap to warrant the expense of such treatment. On the question of the selection of the preservative, the committee reports that, if the timber is to be placed in sea water, where it will be exposed to the attacks of the teredo and other boring mollusks, creosote, or "dead oil" is the only reliable antiseptic. For railway cross-ties, the committee believes that creosote is likewise the most efficient preservative, but on account of its cost it recommends, as more advisable, the use of chloride of zinc (burnettizing). For bridge-timbers, trestles, and other service, where the timber is exposed in comparatively dry situations, it recommends kyanizing (treatment with corrosive sublimate) as the most expedient method.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS OF THE FRANKLIN INSTITUTE, ON THE DELANY SYSTEM OF SYNCHRONOUS MULTIPLEX TELEGRAPHY.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 12, 1884.

The Committee of the Electrical Section acting as a Subcommittee of the Committee on Science and the Arts, to which was referred, for examination,

"PATRICK B. DELANY'S SYSTEM OF SYNCHRONOUS MULTIPLEX TELEGRAPHY,"

respectfully presents the following report, viz.:

Multiplex telegraphy, or the simultaneous transmission of several messages over one line, has been accomplished in several ways with greater or less success. At least three methods are now in use commercially.

(1.) The Duplex and Quadruplex Systems, which are operated by the differential method;

(2.) The Harmonic System, by which several sets of vibrations are set up in the line circuit at different rates of speed; and

(3.) The Synchronous Systems, which transfer the line rapidly to different sets of instruments in rotation. The synchronous system of Mr. Delany belongs to the latter class.

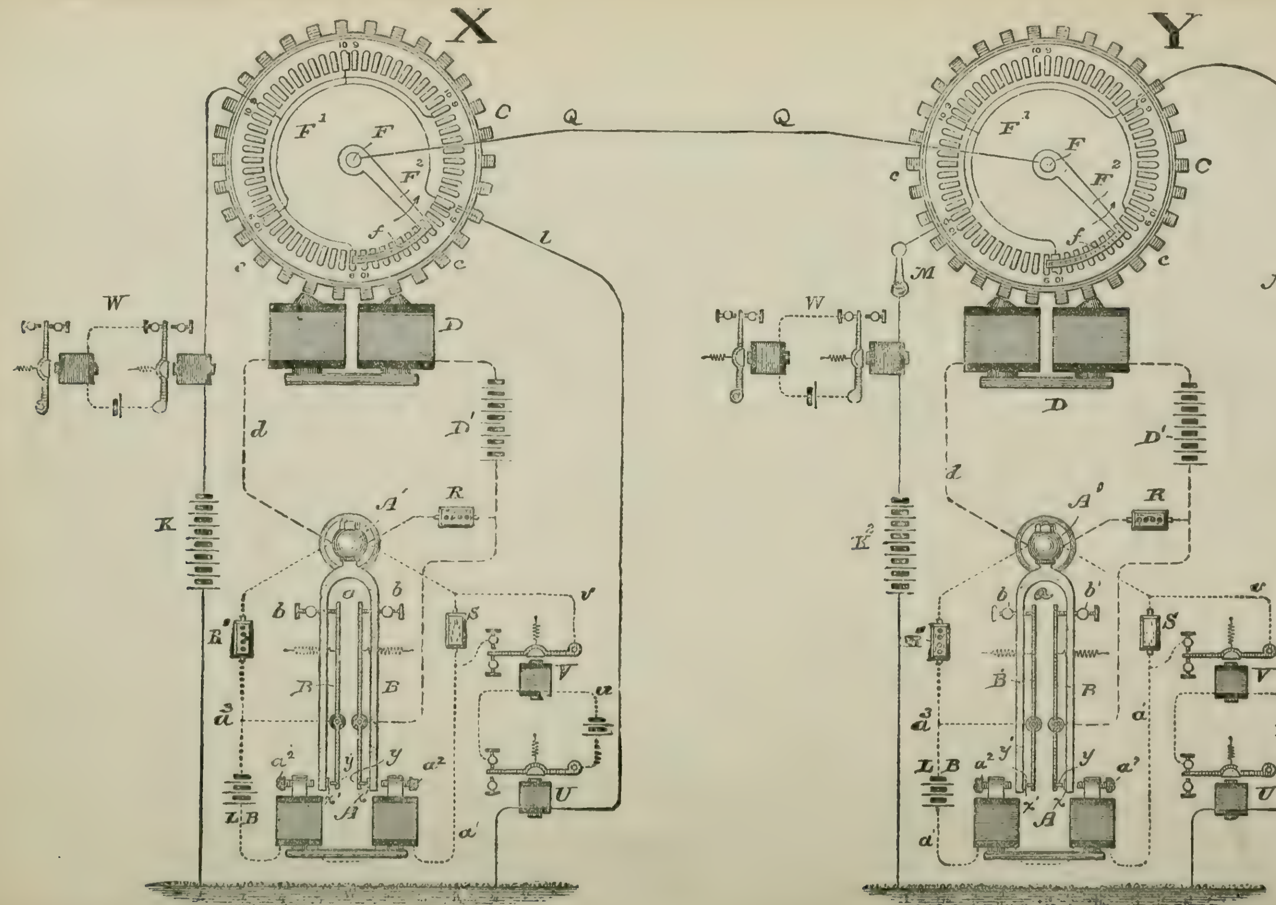
The basis of the synchronous systems is that the moving parts of two instruments, one at each end of the line, shall revolve in exact unison with each other. The difficulty in maintaining the unison under all the conditions of commercial telegraphy, has prevented their adoption commercially, except in the case of the Baudot and the Mayer synchronous systems, which have met with some degree of success in France, and notably on a line between Paris and Marseilles. Mr. Delany's system is based on the phonetic wheel of Paul La Cour, of Copenhagen. This consists of an electro-magnet and a toothed wheel of iron, the teeth or cogs of which, as it rotates horizontally, pass in front of the poles of the electro-magnet. The circuit of the electric-magnet is broken through the medium of the vibrations of a tuning fork; the fork is vibrated by the intermittent pulls of another electro-magnet, whose circuit is also broken by the vibrations of the tuning fork; the toothed wheel, therefore, receives as many pulls per second as the number of vibrations of the tuning fork, and is thus revolved at a uniform rate of speed.

In adapting this wheel to multiplex telegraphy, a trailing arm is attached to the revolving wheel, which is made to pass over a series of contacts arranged as segments of a circle which are insulated from each other. The trailing arm is connected with the line, and, as it rotates, connects the line with each of the segments, one after the other. These segments are in circuit with telegraphic instruments, which are thus successively put in electrical connection with the line. At the other end of the line, there is a similar distributor, with its trailing arm, which connects, in rotation, the same number of segments to the line. If, now, the two distributors revolve in unison, it is evident that corresponding segments at each end of the line will be connected with it simultaneously; when No. 13 segment, for instance, is connected through the trailing arm at one end, No. 13 segment at the other end is also electrically connected, and impulses can be sent from one to the other.

The art had advanced to this stage when Mr. Delany commenced his investigations. It was found that no two tuning forks

could be so accurately attuned that they would vibrate in unison. But it was also found that by increasing the strength of the fork circuit, thus strengthening the magnet which vibrated the fork, its tines would be pulled wider apart and the vibrations would be slower. Making use of this principle, Mr. Delany inserted in the circuit of the magnet of the vibrating fork, a resistance coil, which could be automatically cut out when the vibrations were too rapid, thereby strengthening the current of the magnet, and making the wheel revolve slower. Certain segments in the circle of contacts at each end of the line were used to transmit and receive electrical impulses, which operated to cut out this resistance coil whenever its wheel revolved at a greater rate of speed than the wheel at the other end of the line. Three of these segments are receiving segments, and three are transmitting segments, and as the trailing arm revolves at the rate of nearly three times per second, means are thus provided for about sixteen or seventeen corrections of the movement of the wheel per second. These impulses are sent upon the slightest tendency of one wheel to run faster than the other. Each transmitting segment has its corresponding receiving segment at the other end of the line. When the wheels are exactly in unison, no current passes over the line through these segments, but when the trailing arm at the receiving station is in the slightest degree in advance of the arm at the transmitting station, the circuit is completed, and a correcting impulse is transmitted.

In the accompanying drawings, two sets of instruments, *X* and *Y*, represent two stations electrically connected by a telegraph wire. In the circular table of contacts, there are six independent sets or series. The *9's* and *10's* of each series are used for correcting impulses only. Three of the *9's* on *X*, taken alternately, are connected together, and through a battery to the ground. The corresponding *9's* on *Y* are not connected with anything, but are "dead." The three *10's* following the three dead *9's* are connected together, and thence through a correcting relay, *U*, to the ground. It will be observed that the surface of the three receiving *10's* is extended towards the preceding dead *9's*, making a broad segment. If, now, when the arms, *F*, are revolving, the trailing arm *f*, at *Y*, should reach the broad segment *10* before the trailing arm *f*, at *X*, had left the battery connected *9*, it is evident that an impulse will be sent through the line, which will energize


X
Y
C
Q
Q
F
F
c
l
l'
M
N
W
W
D
D
D'
D'
d
d
K
K
R
R
S
S
U
U
V
V
u
u
v
v
L B
L B

the correcting relay, *U*. The armatures of this relay, by leaving its back-stop instantaneously, cuts out of the fork circuit the resistance coil, *S*, and the fork vibrates slower, as before described.

In the instruments as now constructed, there are seventy-two (72) segments devoted to telegraphy, each of which is put in connection with the line nearly three times per second. The line can thus be used as seventy-two (72) separate circuits for step-by-step printing instruments, each of which can transmit three or four words per minute. Or, if two of the segments are connected with each printer employing one–thirty-sixth ($\frac{1}{36}$) of the wire, six or eight words per minute can be transmitted, and so on for a greater number of segments.

By taking as many as six segments, for instance, every twelfth, and connecting them together and to one instrument, the instrument is connected with the line about seventeen (17) times per second, which makes a current so nearly continuous, that Morse instruments can be worked at the rate of about twenty (20) words per minute. This would allow twelve (12) separate Morse circuits. When twelve (12) contacts are allotted to each instrument, thus dividing the line into six (6) Morse circuits, each one of the six circuits can be worked at the highest rate of speed of which the operator is capable; that is, from forty (40) to forty-five (45) words per minute.

By an ingenious device of Mr. Delany's, these separate circuits can also be worked in either direction with equal facility, so that the line is in every way the equivalent of six separate wires between two points. In this respect it is in advance of the duplex and quadruplex systems now in general use, whose circuits can only be used in one direction; that is, half of the circuits can be worked only in one direction, and the other half only in the other direction.

In any system in which the main circuit is broken rapidly, as in this one, a difficulty is experienced from the static charge of the line, which seriously interferes with its working. To remedy this evil, Mr. Delany inserts between every two instrument segments, a ground segment, not shown in the drawing, which is connected to a central ground plate; the line is thus partly discharged of its static electricity after every battery impulse.

Mr. E. A. Calahan, who is associated with Mr. Delany in the development of this system, introduced one of its most important

features, which is the use of a polarized relay in connection with the Morse method. As this relay responds only to alternate currents of an opposite character, the hitherto insurmountable difficulty of eliminating from the signals the rapid makes and breaks caused by the transfer of the line from one circuit to another, is entirely overcome, and the signals are as clear and sharp as if transmitted over an independent wire.

The line is worked on what is known as the open-circuit principle; that is, the line at the receiving end is connected with the ground through the relay, without battery, and the key of the sending instrument gives alternate positive and negative currents from the battery. One great advantage of the open circuit is, that the greater portions of the evils resulting from defective insulations are eliminated, as, if a sufficient amount of electricity passes over the line to operate the relay at the receiving end, no adjustment of the relay is required to neutralize the effects of a variable current. It may be said to be independent of any variation in the current through leakage, always provided enough current reaches the instrument to operate it.

After holding several meetings, the committee visited the inventor's laboratory in New York, and saw the system in operation over a short wire, both terminals being in the same room. The conditions of an ordinary commercial line were simulated as far as possible by the use of resistance coils, artificial leaks and condensers, and although the instruments worked quite satisfactorily under several severe tests, it was thought best to make no report until a test had been made on a commercial line then being constructed, which was completed in June last, between Boston and Providence.

Soon after the completion of this line, a series of tests extending over several days was made, under the supervision of a member of the committee, first over the line fifty (50) miles long, using the earth for return circuit; and next by looping two wires, making a distance of one hundred (100) miles.

The loop in this case was not used as a complete metallic circuit, but the two ends were grounded at Boston on different earth-plates.

The conclusions arrived at may be stated generally, as follows:

(1.) That the synchronism of the instruments will be main-

tained over that length of line under any conditions which would allow a Morse relay to be successfully worked.

(2.) That in the rare instances in which the synchronism is seriously disturbed, it is restored automatically in from one to three minutes, or it can be restored sooner by proper manipulation by a skilful operator.

(3.) That no adjustment of the relays is required in wet weather, or on account of variable currents.

A public test was made, on which occasion six Morse operators in Boston, and six in Providence, simultaneously worked their respective instruments. On the first test, the six Providence men sent press dispatches simultaneously to the Boston men. In the second test, the Boston men sent dispatches to Providence, and in the third test, three men were sending and three receiving at each end of the line. In all these tests the amount of business done over each circuit was proportioned to the ability of the operators on that circuit. Two first-class men on one of the circuits sent and received as high as forty-three words per minute.

Other experiments were made with five Morse circuits, having twelve contacts each, the remaining twelve segments being attached to twelve printing instruments, all of which were worked successfully, simultaneously with the Morse circuits. A test of the line divided into twelve Morse circuits, each having six contacts, was also made, and a speed of twenty-one words per minute, was attained on a test lasting over an hour.

During the recent Electrical Exhibition, the instruments were worked over a line two hundred miles long, of No. 8 iron wire, with satisfactory results.

The only question to be determined by this experiment was whether the static charge of a line of this length would be discharged soon enough to leave the line free from the succeeding battery charge. The experiment was made with two hundred and forty cells of Callaud battery, divided into two batteries (positive and negative) on one end of the line, and with two batteries of forty-eight Fuller cells each, on the other end. In working from the Fuller end of the line the results were perfectly satisfactory, but in working from the Callaud end, there was a retardation in the signals.

The committee recognizes the fact that the practically perfect synchronism attained by this invention is a most important advance in the art of telegraphy. With synchronism many other things are possible, and it seems quite probable that its uses will not long be confined to the two systems of telegraphy herein described, or even to telegraphy alone. The committee is impressed with the importance of this invention, and unanimously recommends the award of the "Elliott Cresson Gold Metal."

(Signed)

W. W. GRISCOM, *Chairman*,	CHARLES M. CRESSON, M. D.,
ADDISON B. BURK,	W. J. PHILIPS,
ALEX. E. OUTERBRIDGE, Jr.,	E. ALEX. SCOTT, *Ex. Off.*

At the stated meeting of the Committee on Science and the Arts, held Wednesday, March 4, 1885, this report was amended by the incorporation of a recommendation of the award of the "Elliott Cresson Medal and of the John Scott Legacy Premium and Medal," to P. B. Delany; and a recommendation of the award of the "John Scott Legacy Medal and Premium," to E. A. Calahan, and, as so amended, was adopted.

(Signed) H. R. HEYL, *Chairman.*

Adopted March 4, 1885.

A NEW ORDER OF METALLIC SPECTRA.—When, in observing the spark spectra of solutions of metals of the didymium and yttrium families, the liquid itself is made the positive pole, the upper surface of the liquid becomes luminous and gives a spectrum consisting of several nebulous but sometimes brilliant bands lying between 6205 and 4765. Boisbaudran could not trace this spectrum to any of the known cerite metals, and he was unable to obtain it with solutions of the yttrium compounds. It is, however, identical with the bands given by the phosphorescence of pure yttrium compounds, as observed by Crookes, in high vacua. The direct contradiction between these observations will be made the subject of further experiments.—*Jour. Chem. Soc., Sept., 1885.*

AGE OF FOREST TREES.—John T. Campbell reports some interesting observations upon the age of trees, which throw discredit upon the theory that wide, annual rings denote moist and fruitful years, and narrow rings indicate dry years. He finds that two neighboring trees, of the same description and the same age, will have rings of different characters in the same season. The healthiness of the tree, the amount of sun and moisture that it receives, the attacks of insects, the amount of suitable nourishment in the soil, etc., influence the amount of annual growth.—*Amer. Naturalist, Sept. 1885.*

Franklin Institute.

[*Proceedings of the Stated Meeting, Wednesday, March 17, 1886.*]

HALL OF THE INSTITUTE, March 17, 1886.

COL. CHAS. H. BANES, President, in the Chair.

Present—137 members and twelve visitors.

The Actuary reported the election of fifteen persons to membership.

The President made a report of progress on behalf of the Special Committee charged with the work of formulating plans for the future development of the INSTITUTE, and for a new building. He invited members present to submit suggestions, which would receive the respectful consideration of the committee.

MR. JOHN SHINN, of Philadelphia, read the paper of the evening, on "The Cultivation of Flax in the United States." The speaker made an earnest plea for the establishment of the manufacture of the finer grades of linen in the United States. The paper provoked an extended discussion.

On Mr. Burleigh's motion, seconded by Mr. Orr and others, the thanks of the meeting were presented to Mr. Shinn for his interesting and instructive paper. The paper has been referred for publication.

The Secretary's report embraced remarks on the following topics: the Transmission of Power by Electricity: the Smith, Edison and Gilliland System of Telegraphing to and from Railway Trains in Motion, by utilizing the principle of Static Induction, and the uses of Aluminium Alloys in the Production of Wrought Iron (or Mitis) Castings. The following inventions were shown and described: John H. Miller's System of Constructing Air Chambers of Pumps, for Aërating Water under Pressure, etc., P. J. Grau's Improvement in Feed Water Purifiers and the Magnesia Sectional Covering Company's Covering for Steam Pipes.

The Secretary exhibited with the stereopticon, and described, a suite of five photographic views taken in the Caverns of Luray, which were presented to the INSTITUTE by Mr. C. H. James.

Adjourned. WM. H. WAHL, *Secretary.*

A TERTIARY RAINBOW.—Prof. Tait remarks that rainbows due to three or more internal reflections "are too feeble to be observed." It may, therefore, be worth while to record a tertiary bow, which was clearly seen from Thandiani Hill, in the Punjab. The bow extended over an arc greater than a semi-circle, but was broken in two places. The colors were as distinct as in many an ordinary bow. The condition of the sky was specially favorable for seeing a tertiary bow. The sun was low and on nearly the same level with it there were several horizontal layers of cloud of considerable extent, whose nearer, unilluminated sides were therefore dark enough to serve as a good background. There was also a cloud in front of the sun itself, partially reducing its brightness.—*Nature, Oct. 1, 1885.*

BOOK NOTICE.

NOTES ON THE CHEMISTRY OF IRON. By Magnus Troilius, E. M. New York: John Wiley & Sons. 1885.

We have read with considerable interest the "Notes on the Chemistry of Iron" by Magnus Troilius, E. M., and although we have been unable to find anything strikingly new or original, yet the author has so successfully culled, from a vast amount of scattered information on the subject, all the essential requisites for a complete system of iron and steel analysis, that few workers in that field can afford to do without this valuable contribution to the literature of the subject.

It would be highly advantageous to the profession, for specialists in the various branches of Analytical Chemistry to publish just such "Notes." They are far more valuable to the worker than the more pretentious works can hope or expect to be, for it is from just such "Notes" that the larger works on chemistry are compiled; and it is in discarding the details of the *modus operandi* of various methods that they lose their value. It too frequently happens that authors are not familiar personally with the methods they describe, and therefore omit what appear to be trifling minutiæ, but which in reality (once the principles have been mastered) are essentials. For it is in the accumulated knowledge of a vast number of experiments made under the same conditions; or, in other words, the results of experience, that the advantages of a particular method are to be found, and these advantages constitute the "wrinkles" of the most experienced chemists. In these days of specialties, it is well-nigh impossible for a chemist to be posted in all the branches of that complex science, but he is frequently called upon to work in fields where he has had only the most superficial experience. In such cases "Notes" similar to those Mr. Troilius has published, for example, "Wanklyn's Water and Milk Analysis," and Hempel's "Neue Methoden für Analyse der Gase," are exceedingly valuable. We feel that they are thoroughly reliable and therefore authoritative.

We believe it would have been in better taste for Mr. Troilius to have given personal credit for the various methods and apparatus proposed and designed by others.

The platinum tube for carbon combustions we believe was first used and described by Mr. Andrew Blair, of Philadelphia, and the methods described for determining phosphorus and manganese are due to Dr. Tamm and Mr. Ford, respectively. We must also enter our protest to the sweeping assertion that "the disadvantages of the permanganate solution are so great, that it has almost everywhere been abandoned in favor of the bichromate" We believe that nine chemists out of ten, at least in this country, use the permanganate solution in the determination of iron.

These, however, are not vital matters, and, taken altogether, we must congratulate Mr. Troilius on having supplied a long-felt want, and we hope that his little book will have the full measure of success that it certainly deserves.

P. G. S.

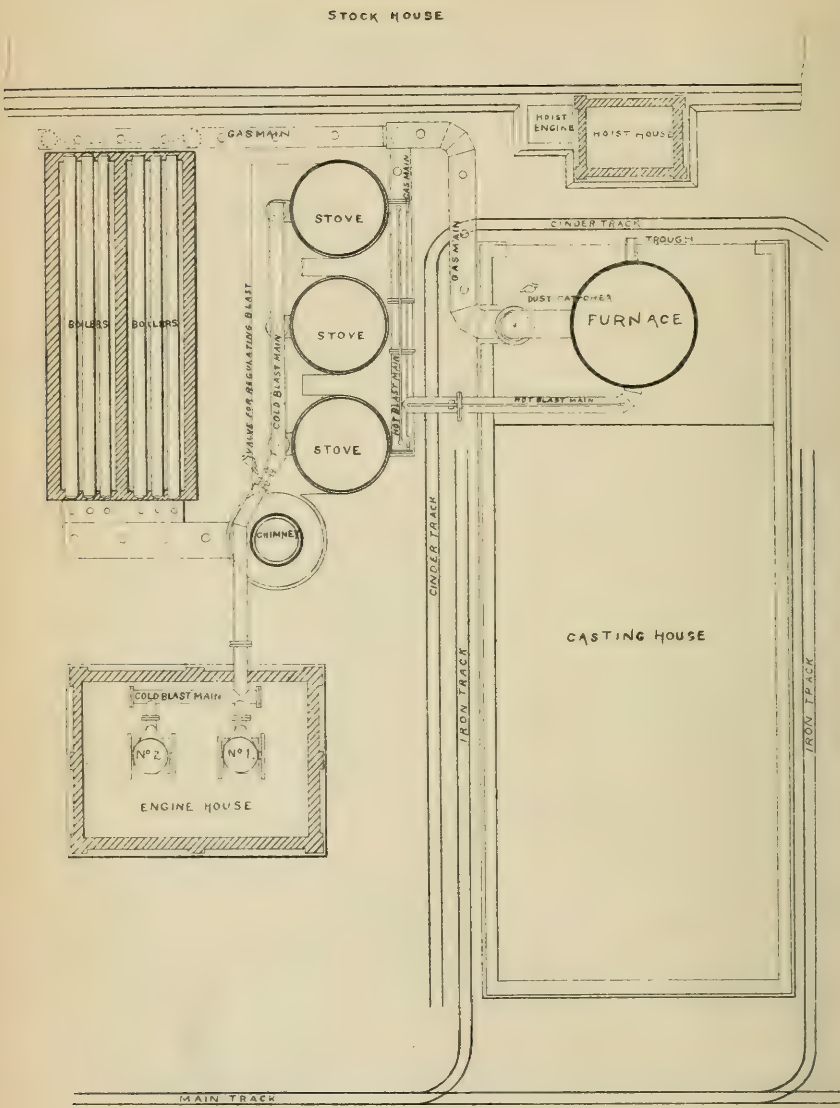


PLATE I.

ARRANGEMENT FOR A FURNACE PLANT.

// JOURNAL
OF THE
FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA,
FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXI. MAY, 1886. No. 5.

THE BLAST FURNACE.

BY JOHN M. HARTMAN.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 22, 1886.*]

The process of making cast iron in a blast furnace may be divided into three parts:

(1.) Deoxidizing the ore.

(2.) Carbonizing the deoxidized ore.

(3.) Liquefying the deoxidized ore.

All iron ores are essentially oxides, and may be divided into five species:

(1.) Protoxide of iron, in which the atomic ratio of oxygen to iron is one to one, as in fayalite.

(2.) Magnetic oxide of iron, in which the ratio of oxygen to iron is one and one-third to one, as in magnetite.

(3.) Sesquioxide of iron, in which the ratio of oxygen to iron is one and one-half to one, as in hematite.

(4.) Hydrated sesquioxide, in which the ratio of oxygen, iron, and water is one and one-half to one, to three-fourths, as in limonite.

(5.) Carbonate of protoxide of iron, in which the ratio of oxygen, iron and carbonic acid is one to one to one, as in siderite.

In addition to the above, there is the artificial ore or rolling-mill cinder, from which iron is extracted, and which corresponds in composition to fayalite.

Practically, in facility for reduction, these ores rank as follows:

(1.) Siderite or carbonate.

(2.) Limonite or hydrate.

(3.) Hematite or sesquioxide.

(4.) Magnetite or magnetic oxide.

(5.) Fayalite or silicate of protoxide of iron.

The magnetic oxide is a firm stable compound and retains its oxygen tenaciously. In some cases as with that from Pilot Knob hematite ore is so dense and hard, that it is classed with magnetite for difficult reduction. The difficulty in reducing fayalite or rolling-mill cinder is to keep the silicate from fusing before the oxygen is abstracted, as a pasty silicate is formed at a low temperature, over the surface of the ore which seals up the oxygen and prevents the CO from abstracting the oxygen.

Substantially, none of the these ores exist as pure oxides of iron, but are always found in combination with one or more of the following: silica, alumina, lime, magnesia, manganese, sulphur, phosphorus, water, carbonic acid.

Fayalite varies from fifty-eight to sixty-nine per cent. of protoxide, giving about forty-five to fifty-four per cent. of iron.

Rolling-mill cinder varies from fifty-two to sixty-seven per cent. of protoxide, giving about forty to fifty-two per cent. of iron.

Magnetite varies from fifty-five to ninety-three per cent of magnetic oxide, giving about forty to sixty-eight per cent. of iron.

Hematite varies from fifty-seven to ninety-seven per cent. of sesquioxide, giving about forty to sixty-eight per cent. of iron.

Limonite varies from fifty-seven to eighty per cent. of sesquioxide, giving about forty to fifty-six per cent. of iron.

Siderite varies from forty-two to sixty per cent. of protoxide, giving about thirty-five to forty-seven per cent. of iron.

The remainder to make 100 per cent. by weight of any of the above ores, is composed of one or more of the nine substances before mentioned, in varying proportions. The earthy matters in which the ore occurs are called the gangue.

The oxygen of the ore is separated principally by carbonic oxide generated from the fuel.

The fuel may be divided into four species:

(1.) Charcoal, which is obtained by driving off by heat, the water and volatile matter from wood, leaving a residue containing about eighty-six per cent. carbon, two and one-half hydrogen, one and one-half oxygen, seven water, three-tenths ash.

(2.) Coke, which is obtained by driving off by heat the volatile matter of bituminous coal, leaving a residue containing about eighty-six per cent. carbon, two per cent. volatile matter, one per cent. sulphur, eleven per cent. ash.

(3.) Block coal, containing about fifty-six and one-half per cent. carbon, thirty-two and one-half volatile matter, eight and one-half water, two and one-half ash.

(4.) Anthracite, containing about eighty-eight per cent. carbon, three and one-half volatile matter, two-tenths per cent. sulphur, eight per cent. ash.

Charcoal is a porous, bulky material that will fire at 800°, burns away quickly, and causes a furnace charge to settle rapidly.

Coke is porous, less bulky, fires at 900°, burns moderately quick, and causes a furnace charge to settle rapidly; used with anthracite, it eases up the pressure and permits more air to pass through the furnace.

Anthracite is dense, hard, bright, gives off carbonic oxide slowly, and at a high heat is pasty and has a tendency to stick together. It burns slowly, and having no pores like coke, it burns on the surface only, requiring a large surface of contact to carburize a cubic foot of air per minute. In the blast furnace, it requires care to work alone, but with twelve to twenty-five per cent. of coke, good results are obtained. When properly handled, a pound of anthracite will do the same work as a pound of coke, but it takes more blast pressure and stronger blowing engines.

The gangue, or foreign acid elements of the ore, are liquefied by the base or bases obtained from limestone or oyster shells.

Limestone may be divided into two species:

(1.) Calcite, containing from fifty-four per cent. lime, forty-two per cent. carbonic acid, four per cent. silica, alumina and iron, to fifty per cent. lime, forty per cent. carbonic acid, and ten per cent. silica, alumina and iron.

(2.) Magnesian limestone, containing about thirty per cent. lime,

twenty per cent. magnesia, forty-six per cent. carbonic acid, and four per cent. silica, alumina and iron, to forty-four per cent. lime, five per cent. magnesia, forty-one per cent. carbonic acid, ten per cent. silica, alumina and iron.

A ton of coke or anthracite containing ninety-three per cent. carbon and two per cent. ash, is worth to the iron master, say, $3.68, while that containing seventy-five per cent. carbon and fourteen per cent. ash is worth only $2.74. An ore containing forty per cent. iron, twelve per cent. silica, is worth, say, $3.71; one containing forty per cent. iron and thirty per cent. silica is worth only $2.39. An ore containing sixty per cent iron and four per cent. silica is worth, say, $6.58. An ore containing sixty per cent. iron and ten per cent. silica is worth $6.12. A limestone containing one per cent. of silica is worth, say, fifty-four cents; a stone containing fifteen per cent. of silica is only worth fourteen cents. A furnace using forty per cent. ores with twelve per cent. of silica will make, say, 820 tons per week, but with forty per cent. ores and thirty per cent. silica will make only 500 tons. The same furnace, with sixty per cent. ores and four per cent. silica will make 1,211 tons, and with sixty per cent. ores and ten per cent. silica will make 1,039 tons. Furnace plants are in ruin to-day that have neglected to go over these matters carefully.

Oyster shells are practically pure carbonate of lime, but their use is limited to a few furnaces on the sea coasts.

The fuel is oxidized by the blast or air which is composed of twenty-three per cent. oxygen and seventy-seven per cent. nitrogen. Such are the materials used in the production of pig iron, and sound judgment must be used in their selection to make a commercial success.

The iron master having secured his supplies, selects a site for the blast furnace plant, the general arrangement of which is exhibited in *Plate I.* In making this selection, the following points have to be considered.

(1.) Transportation of the raw material to the furnace.

(2.) Transportation of the pig iron to market.

(3.) If possible, a site on competing lines of railroad.

(4.) A water supply of, say, 750 gallons per minute for each furnace.

(5.) A level plot of, say, four acres above high water, and well drained.

(6.) A cinder dump of thirty-five acres of rough land.

The size of the furnace will be governed by the fuel.

As a maximum for charcoal, say, bosh of twelve feet.

As a maximum for coke, say, bosh of twenty feet.

As a maximum for anthracite, say, bosh of seventeen feet.

Larger boshes are used but are not giving the results of smaller boshes.

The heights will be determined by the reductibility of the ores, as sufficient time must be allowed for their exposure to deoxidize them.

With siderite or carbonates fifteen hours exposure will be required.

With limonite or hydrates seventeen hours exposure is wanted.

With hematite or sesquioxide twenty hours.

With magnetite or magnetic oxide twenty-four hours.

With fayalite or rolling-mill cinder thirty hours.

These are average figures, but shorter time can be used by using more fuel. For instance, the Mount Hope Furnace made No 1 charcoal pig with only seven hours exposure, but it used an excess of charcoal. The ore was a fine disintegrated hematite. In another instance, a furnace 13x65 feet, working with another 20x80 feet, on same stock, it was found the small furnace carried the same burden as the large one when using easily reduced ores, but with refractory ores the higher furnace carried more burden.

To determine the size of a coke furnace, the volume of air must be first determined. Say 24,000 feet per minute is used. This must have a crucible of sufficient size to use it which will be eleven feet diameter, and allowing four and one-half feet for angle of bosh on each side will give twenty feet of bosh. This crucible will consume 17,280 pounds per hour of an eighty-six per cent. carbon coke, which, with its proper burden of, say, hematite ore and limestone will take up 1,217 cubic feet of space per hour, which, multiplied by twenty hours time required for reduction, gives a furnace of 24,340 cubic feet contents, or ninety feet high.

For an anthracite furnace using, say, 18,000 feet air per minute, the crucible would be ten feet diameter, allowing for angle of bosh would give bosh seventeen feet diameter. This crucible will consume 11,514 pounds per hour of an anthracite containing eighty-eight per cent. carbon, which, with its proper burden of, say,

magnetic ore and stone, will take up 410 cubic feet, which, multiplied by twenty-four hours required for reduction, gives 9,840 feet contents, or a furnace seventy-five feet high.

The tuyere nozzles for the twenty-foot coke furnace would be eight of six inches diameter, giving a velocity of 15,000 feet per minute.

Tuyere nozzles for seventeen feet anthracite furnace would be eight to four and one-half inches diameter, giving a velocity of 20,000 feet per minute.

The angle of bosh should be 75°.

The diameter of bell equals one-half diameter of bosh, as a general rule.

The stock line at top under the bell can vary from one foot to two feet less in diameter than the bosh, according to heights above bosh.

The foundation of the furnace is built of stone, leaving in the centre an opening five feet deep, which is filled with fire-brick forming the hearth or bottom. On the foundation, are placed cast iron columns, about twenty-four feet high, on which is bolted a cast iron mantel. To this mantel is attached a heavy boiler plate jacket, extending from thence to top of furnace. On the bottom, or hearth, is placed a cast iron crucible jacket extending 18 inches below the hearth and 8 feet above hearth. This jacket has an offset in it just below the tuyere to give thicker walls to the crucible below the tuyeres, and has an opening at hearth level to draw off the iron. This jacket has one inch coils cast in it, through which water circulates to keep them cool and prevent burning of the walls. Suitable openings are left in the jacket six feet from hearths to centre for tuyeres and one 3 feet 9 inches up for the cinder notch. From the top of this crucible jacket up to the mantel, is placed a heavy wrought iron bosh jacket which is cooled by a water coil inside of it, in event of a scaffold, localizing the heat.

The crucible walls below tuyere are twenty-seven inches thick at the tuyeres, and to top of bosh the walls are eighteen inches thick, and are supported by the bosh jacket. From the top of the bosh to top of furnace, there is a single thickness of brick thirty inches long, and back of it is placed two inches of mineral wool for expansion of the brick. On the top of the furnace is placed

the wheeling plates and bell and hopper. From the top of furnace, a flue leads to the boilers and stoves to convey the gas to them for generating steam and heating blast. This flue contains numerous pockets, which catch the dust and dirt in the gas and prevents it from reaching the stoves.

The engines are generally vertical high pressure engines, but for good work at furnaces condensing engines are required. . They run with a maximum piston speed of 300 feet per minute. Their piston area should be in ratio of two of steam to three of blowing piston, and they should be strong enough to blow twenty pounds per square inch when required. The boilers are plain cylinders about 40 inches diameter, say, 70 feet long, with 30-inch heaters 55 feet long under them, arranged in sets of two or three each. The stoves to heat the blast are fire-brick regenerative stoves, *Plate II*, requiring three for each furnace. They are used alternately, one on blast and two on gas. They consist of a heavy air-tight shell with a dome top, and are lined throughout with fire-brick. Inside, at front, is placed a combustion chamber over which Gothic arches are sprung. On these Gothic arches are built walls called regenerators, crossing each other at right angles, and leaving openings 9 x 9 inches vertically through them. The dome is lined with two courses of nine-inch brick.

Across the centre of the stoves, and extending from the bottom of stove up to the bottom of the dome, is a division wall to turn the current of gas and blast. On the other side of this division wall, are placed walls called regenerators 2½ inches thick, at right angles to each other, leaving openings 5 x 5 inches in them. These openings extend to within a short distance of the bottom. The thin walls are supported on girders and piers under them at the bottom. On the front of stoves are placed a water-cooled, hot-blast valve, two gas valves, and two blow-off valves. The hot blast valves are to let on and cut off the blast from the furnace. The gas valves are to let on and cut off the gas from the stoves. Two valves are used to prevent any leakage of hot blast back into the flues which fires the gas, burns the valves, and destroys the flues. Between these two valves is placed a small valve which is slightly weighted. If any blast passes the first valve, it pushes open this small valve, and escapes to the air, thereby preventing it entering the flue. The blow-off valves are to relieve the stove

from pressure when they are changed from blast to gas. They are piston valves operated by blast pressure. On turning the four-way cock attached to them, they fly open, relieving the internal pressure of the stoves, and at the same time sweeping out the dust that has been deposited in the regenerators, keeping them clean and in good order. The gas ashes or dust has the strongest affinity for the part of the stove that is the hottest, which in this stove is the Gothic arches. As all the blast sweeps quickly over them. when the blow-off valves are opened, the dust is removed each time after it is formed. These valves are then left open to admit air to burn the gas. The combination of the pockets (before mentioned) in the flue and these blow-off valves at the bottom of the combustion chamber has resulted in keeping the stoves clean for two years up to the present time. When the stoves require to be cleaned at the end of the blast, a crane swinging under the dome is used. On the back of the stoves are placed the chimney valve and cold blast valve.

With one substantial division wall in the centre of stove there is no danger of leakage through the wall by cracking and leave the gas pass direct without traversing the whole stove as occurs where more division walls are used. These division walls give but little heating surface and occupy the best part of the stove. The dome is the strongest and most substantial top for stoves, and with one division wall requires but one opening in the top, which dispenses with the skeleton walls at top where a number of openings are used. These skeleton walls are continually giving way, causing stoppages and annoyances.

To operate these stoves, gas is admitted by the gas valves, burned in the combustion chamber in contact with massive walls, escapes up through the nine-inch openings of the first regenerator into the space under the dome, thence it turns over the division wall, down through the five-inch openings, escaping through the valve at bottom to chimney. Any imperfect combustion in the combustion chamber is finished in the second combustion chamber, or space under dome. Gas in combustion expands and ascends, after combustion there is no further expansion, and, as its heat is absorbed, it contracts and descends. In the first regenerator, there is combustion and an upward current; in the second regenerator, absorption and a descending current working in

accordance with natural laws, and requiring less height of chimney. After gas has burned through a stove for four hours, the gas valves are closed, the bottom blow valves are closed, the chimney valve is closed, the cold blast valve opened, which leaves the blast into the stove. The hot blast valve is then opened, leaving the blast pass through the stove to the furnace. The next stove is then cut off from the furnace and put on gas to be heated up again. Using three stoves, gives two on gas heating up, with one on the furnace. The blast, sweeping through the stove, carries the heat absorbed by the fire-brick walls into the furnace, heating the blast 1,500° when required. This is maintained for two hours, during which time it will lose about 50° if the stoves are large enough. The escaping gas should never pass off over 350°.

Stoves with five square feet of surface in the combined regenerators to each cubic foot of air per minute will be found ample. Unless large surfaces are used, the walls glaze and lose their efficiency. All the valves are placed at the bottom of the stove, where they can always be under the eye of the stove tender, and are made so that they can be instantly taken apart and repaired. By burning more or less gas through them, the temperature can be regulated at will. The brickwork at the bottom of the combustion is massive, which retains the heat and fires the gas immediately on its entrance to the stove. This avoids the explosions which heretofore shattered the brickwork. Fire-brick stoves cannot be destroyed, they last longer, cost less for repairs, and use less gas to heat 1,600° than pipe stoves to heat 900°. In practice, it is found that taking iron pipe stoves at their ordinary limit of 900°, and replacing them with brick stoves using 1,400°, that there is a saving of fifteen per cent. in the fuel, and an increase in the make of iron amounting to twenty per cent.

Air or steam hoists are used to elevate the stock to the top of furnace from the stock house. The stock house is an iron building with two or four railroad tracks through it, which are elevated, say, sixteen to eighteen feet above the floor. It is divided off into bins for the storage of stock of different kinds, which is dumped into the bins from the cars overhead. In the stock house, at the bottom of the hoist, are placed suitable scales to weigh all the material that goes in the furnace. Strict attention has to be paid to this, as the whole operation depends on the proportions, by weight, of fuel,

ore and stone. Iron barrows are used to convey the stock from the bins to the scales, where they are balanced, sent up the hoist, and the contents dumped in the hopper. Various devices of draw bins have been tried, but the old arrangement of shovelling the stock in barrows has proved the cheapest and best. Skip hoists, to dispense with barrows going to the top, have been tried, but, so far, have not superseded the old arrangements of barrows.

In starting a furnace the first thing is to determine what the composition of the cinder shall be. A good cinder with ores not containing over one-half sulphur will be silica, thirty-eight per cent.; oxide of iron, two per cent.; oxide of manganese, five per cent.; alumina, ten per cent.; magnesia, seventeen per cent.; sulphur, two-tenths per cent.; lime, twenty-eight per cent. When there is much sulphur in the stock more lime must be used. A cinder of the following formula is good, $(2\ R_2O_3,\ 3\ Si\ O_2) + (2\ RO,\ Si\ O_2)$. Lime can replace the magnesia, and alumina replace either to a limited extent. The calculation for the cinder is made by getting all the substances in per cent. in the fuel, ore and limestone, then on separating the acids and bases, it will be found that the acids predominate. Limestone is then added to saturate the acids, giving generally two atoms of base to one of acid. Great care is necessary in selecting limestome to get it free from silica, as every pound of silica in the stone requires two pounds of lime to saturate it. A pure limestone contains but fifty-six per cent. of lime. Suppose the stone used contains fifteen per cent. of silica, then thirty per cent. of lime is required to saturate the silica in the stone, leaving only twenty-six per cent. of lime to saturate the silica in the ore. This requires more limestone, more coal, makes more cinder and less iron.

Charcoal is used in the sizes that it comes from the kiln, coke the same, averaging, say, five-inch cubes. Anthracite should be used in sizes not exceeding four-inch cubes, and ores should not exceed three-inch cubes if uniform work is wanted. Ore crushers will break the ore cheaply; it is much better and cheaper to disintegrate the ore mechanically to three-inch cubes than to depend on the furnace doing it chemically, and producing irregular iron. The dust and fine ore made by the crushers can be used by wetting it before charging it. This will allow it to get well down in the furnace before it dries. The larger, denser lumps of ore get through

the zone of fusion with greater part of their oxygen, and if not reduced by solid carbon before reaching the zone of combustion they melt, making a black scouring cinder that annoys a furnace man. Lumps of magnetite have been found at the tuyeres with their surfaces reduced in for a quarter of an inch, while the balance was magnetic oxide as put in at the top. Large ore can be used, but it is done at the expense of fuel, irregular quality, and less output of iron. Limestone should also be broken, that it may part with its carbonic acid in the upper part of the furnace before reaching a high temperature.

In the first filling of a furnace small channels are formed by loosely laid red brick on the hearth. These channels lead to the front and supply fresh air to the burning wood. The crucible is then filled with short dry wood up to the off-set or starting of the bosh, and from that point up for about two-thirds the height of the bosh is filled with coke to form a bed. Then follows a burden composed of one of coke to one-quarter of ore, and the proper amount of limestone to top of bosh, then

1 of coke to		1/3 of ore, etc., for		10 feet up, then		
1	"	"	1/2	"	"	15 " "
1	"	"	1	"	"	15 " "
1	"	"	1 1/4	"	"	the balance to top.

The wood is then fired, leaving the tuyeres and iron notch open, water is turned through the tuyeres and breasts, and after six or seven hours burning the wood will be gone and cinder found trickling down the walls. The tuyere pipes are then put up, and blast heated about 500° turned on, say, about one-half the volume to be regularly used. The gas at top will fire after the wood is fired say five hours, and must be ignited to prevent an explosion. Soon as blast is turned on the bell at top is closed and the gas passes down the flue to the boilers and stoves, where it is burned for purposes already described.

After blast is on the furnace for eight or ten hours cinder will be up to the cinder notch. The iron notch is then opened and the cinder drawn off at the hearth level. This is repeated for three flushes, which cleans the hearth of the ashes and mucky cinder, heating it up and preparing it to hold a large volume of iron. The iron that flows out with these three flushes is skimmed off and sent back to the top of furnace to be re-melted. After

the third flush the cinder is drawn off at the cinder notch, and, if cinder is made rapid enough, the notch is allowed to flow constantly until next casting time, when it is closed. After eighteen to twenty hours, iron enough will have accumulated in the hearth to make a cast, when it is run out into pigs. The water is now turned through the jacket. The blast is increased as fast as the cinder will admit, which is judged of by its limpidity or flow, and the ore with its limestone is increased, judging by the grade of iron; that is, the hotter the iron the more burden can be used. The heat in the blast is held in reserve to increase or decrease the heat in the furnace as may be required.

After blast is put on, there should be no stoppage for thirty-six hours at least, when the furnace will be out of danger. The burden, volume of blast, and heat in blast, must be increased so that in six days the furnace will be up to her full capacity, as the walls and hearth will be fully saturated with heat by that time.

The furnace having started successfully, then comes the important matter of burdening her to make a given grade of iron with the least fuel. The fuel unit having been fixed at, say, 2,000, 3,000, or 4,000 pounds per charge, is never varied, but the ore and stone are varied to suit circumstances. For a general rule (but use cautiously), say, fuel contains eighty-eight per cent. carbon, 1,400 pounds fuel are required for reduction and carbonization of ores, and for each pound of cinder $\frac{31}{100}$ pounds fuel is required, which, with 1,200° to 1,300° hot blast, and not over five-tenths of one per cent. of sulphur or manganese in the burden No. 1 iron should be made, and for each grade of iron below No. 1 three per cent. less of the fuel will be required. No. 1 is a dark, large, open grain soft iron, containing about 92·40 iron, 3·50 graphitic carbon, ·13 combined carbon, 2·40 silicon, the balance being alumina, sulphur, phosphorus, manganese, etc. No. 2 is not so dark, finer grain, a little harder, tougher, and contains 93·00 iron, 3·20 graphitic carbon, ·48 combined carbon, 2·30 silicon, balance alumina, etc. No. 3 is gray color, fine grain, hard, and of high tensile strength, containing 93·66 iron, 2·32 graphitic carbon, 1·23 combined carbon, 1·94 silicon, balance alumina, etc. No. 4 is white mottled with gray spots, is harder than No. 3, of higher tensile strength and rather brittle, containing 94·25 iron, 2·10 graphitic carbon, 1·36 combined carbon, 1·30 silicon, balance alumina, etc. No. 5 is white

iron, no grain, extremely hard and brittle, containing ninety-five per cent. iron, ·36 graphitic carbon, 2·80 combined carbon. ·50 silicon, balance alumina, etc. While with all other metals their value increases with their purity, pure iron has no commercial existence, being simply a brown powder that will burn off to oxide of iron if exposed to the air. The small percentage of carbon with it is what gives its strength and value. The other elements in it change its character somewhat. Silicon softens pig iron, while sulphur and manganese harden it. Silicon and phosphorus make iron fluid or easy melting and weak, while sulphur retards its fluidity but makes it stronger.

Some furnace men sub-divide the above grades, which confuses the market. If iron will not pass strictly for a certain number put it in the grade below, which gives the iron a better standing in the market and retains customers in dull times.

Nos. 1 and 2 are foundry irons for castings.

No. 3 is used for both castings and wrought iron.

Nos. 4 and 5 are forge irons for making wrought iron.

Nos. 1, 2, and 3, when not over ·20 phosphorus, are used to make Bessemer steel.

An important subject is the proper temperature in the different portions of the furnace. All efforts to decrease the consumption of fuel and improve the working of the furnace must be based upon it.

Tracing the thermic conditions from below upwards, we have at the bottom of a blast furnace (*Plate III*), making No. 3 iron, a temperature of 2,900° F., which increases slightly to a point a little below the tuyeres. In the immediate vicinity of the tuyeres the temperature is somewhat lower, owing to the entering blast; but a short distance above the tuyeres, where all the oxygen of the blast has been converted into carbonic acid, the highest temperature in the furnace is attained. This carbonic acid is, however, almost as soon as formed, converted by the glowing coal into carbonic oxide, a process which absorbs heat, reduces the temperature, and provides the active agent for the reduction of the iron ores. In its ascent, the hot carbonic oxide gradually parts with its heat, first fusing the descending iron and earthy materials, which trickle down to the hearth of the furnace. The limit of this zone of fusion is rather sharply defined, and the temperature in this zone

suddenly decreases by the heat absorbed and made latent by the fusion. Passing on up, the carbonic oxide gas absorbs the greater part of the oxygen of the ores, forming carbonic acid, increasing the temperature, and leaving the iron reduced to a sponge. The oxide that escapes reduction by CO is then reduced by contact with solid carbon, or fuel forming CO, and causing a loss of heat compared with the reduction by CO to CO^2. In its further ascent, the hot gas drives off the carbonic acid from the limestone, which causes an additional absorption of heat, and finally the gas escapes at the top, at a temperature of about 250° F., if the furnace is working well. These changes of temperature are represented graphically, without regard to actual values, in *Plate III*[a] by dotted lines *a*, *b*.

If, now, we reverse the direction of the investigation, and trace the thermic conditions involved in the descent of the coal, ore and limestone, we find that the charges descending at the rate of about three feet per hour (if the furnace is driven properly), become heated at the expense of the ascending hot gas. At a temperature of about 570° F., the ores begin to be reduced, or to lose their oxygen under the influence of the carbonic oxide. The quantity of heat absorbed in deoxidizing the ores being less than that developed by the formation of carbonic acid, an increase in temperature is the result. Further down, at a temperature of about 750°, the limestone begins to part with its carbonic acid, a somewhat higher temperature being necessary where dolomite is used. Still descending, the point is reached where the earthy matters are fused together as cinder, and the iron separates from them. From this fusion limit downward to a point about three feet above the tuyeres, an atmosphere of carbonic oxide exists, which prevents the oxidation of the falling shots of iron, and reduces any fugitive pieces of ore which may have escaped the zone of fusion. From about three feet above the tuyeres to about six inches below them, an atmosphere of mostly carbonic acid exists. This space is called the zone of combustion, and it is upon the area of this region that the rapidity of the driving of the furnace, or the volume of entering blast, depends. From the hearth, or bottom of the furnace to the zone of fusion, the furnace is filled with glowing coal, although occasionally a stray piece of refractory ore or stone will be found here, which is reduced by contact with

solid carbon generating carbonic oxide with a loss of heat. This iron not being thoroughly carbonized mixes with the iron in the hearth and lowers its grade, by decreasing the graphitic carbon in the iron already in the hearth.

This bed of glowing coal acts as a filter or screen to take up all oxygen or carbonic acid before reaching the zone of fusion, and thereby to maintain a powerful reducing atmosphere immediately below and in the zone of fusion, as well as above it for some distance. The deoxidized ores as a sponge entering the zone of fusion with its intense heat have such a strong affinity for oxygen that they will split up any carbonic acid which may have escaped reduction in the bed of glowing coal, rob it of one atom of oxygen, the sponge burning to oxide of iron, which escapes and shows at the chimney top in a peculiar brownish-red smoke.

The heat in the hearth of a blast furnace is the result of the combustion of the fuel by the blast, to which is added, in the case of hot blast, the heat brought in with the air, and the heat brought down by the descending stock. It is evident that if the blast be cold a correspondingly larger amount of fuel must be employed to maintain the same amount of heat in the hearth than when hot blast is used. A temperature of blast of 800° F. is needed to ignite charcoal, of 900° to ignite coke, and fully 1,300° to ignite anthracite. The convenience and advantage of contributing to the heat of the hearth by heating the blast is now fully understood.

Running on a burden of one pound of coal to one pound of ore, more heat is developed than is required. The descending stock cannot absorb the large volume of heat coming up, and consequently the furnace becomes hot to the top, as shown by *Plate IV*. This excess of heat is partly absorbed by the decomposition of some of the carbonic acid in the gas by the glowing coal at the top, carbonic oxide being formed. As this amount of coal is lost to the furnace, it is wasted. This waste, however, acts advantageously by causing less coal to reach the hearth, and thus hindering the make of iron high in silicon.* This evil exists more widely than is generally supposed, as it is, to a certain extent, self-corrective. If the burden is increased, say two pounds of ore to one of

* Before the coal gets to burning at the top, in this case, iron high in silicon is always made. The excess of fuel heat on long exposure reduces the silica in the fuel.

coal, and the same volume of blast used, then the heat returned per hour to the hearth from the ore and stone will be double. This heat, in combination with a higher temperature of the blast, replaces the pound of coal which it saves, and at the same time doubles the yield of iron.

Concentration of heat at the tuyeres and in the hearth is one of the first aims for successful furnace work. This can be obtained only by large hearths, hot blast, heavy burden, and rapid driving by using a large volume of hot blast. The descending stock in the furnace collects the heat from the ascending gas and carries it down to the hearth again, increasing the intensity of combustion at the tuyeres—an important matter, when it is considered that the intensity of combustion heating the hearth determines the grade of iron.

The iron arriving at the hearth contains combined carbon but no graphitic carbon. The intense heat of the hearth changes the greater part of the combined carbon to graphitic carbon, and as the hearth is more or less hot so will the iron be grayer or whiter by the change. Buckshot iron is due to colder hearths and consequent sticky cinder which entangles the shots of iron and will not allow them to separate. It invariably accompanies sulphur, either in the ore or fuel, which requires a heavy lime cinder to take up the sulphur and avoid white iron. The more limy the cinder the higher is the heat required to fuse it.

The descent of stock in the furnace is governed entirely by the rapidity of combustion at the tuyeres. A true test of the furnace is the number of tons of fuel consumed in twenty-four hours, and the greater the proportion of ore in the burden, the larger will be the yield of iron if the furnace process is properly managed. In *Plate III*, it will be noticed the zone of reduction (colored red) is low down in the furnace compared with *Plate IV*. This prevents the CO^2 of the limestone being driven off in the presence of a high heat and combining with the fuel to waste it by forming CO near the top of the furnace as in *Plate IV*, and giving the CO no time to act on the ore. The stock entering the furnace, *Plate III*, is gradually heated, the ores well reduced at a low temperature, and there being but little excess of heat to reduce silica to silicon the resulting pig iron is low in silicon, strong and dark in color. The furnace being driven rapidly, and the heat development and heat

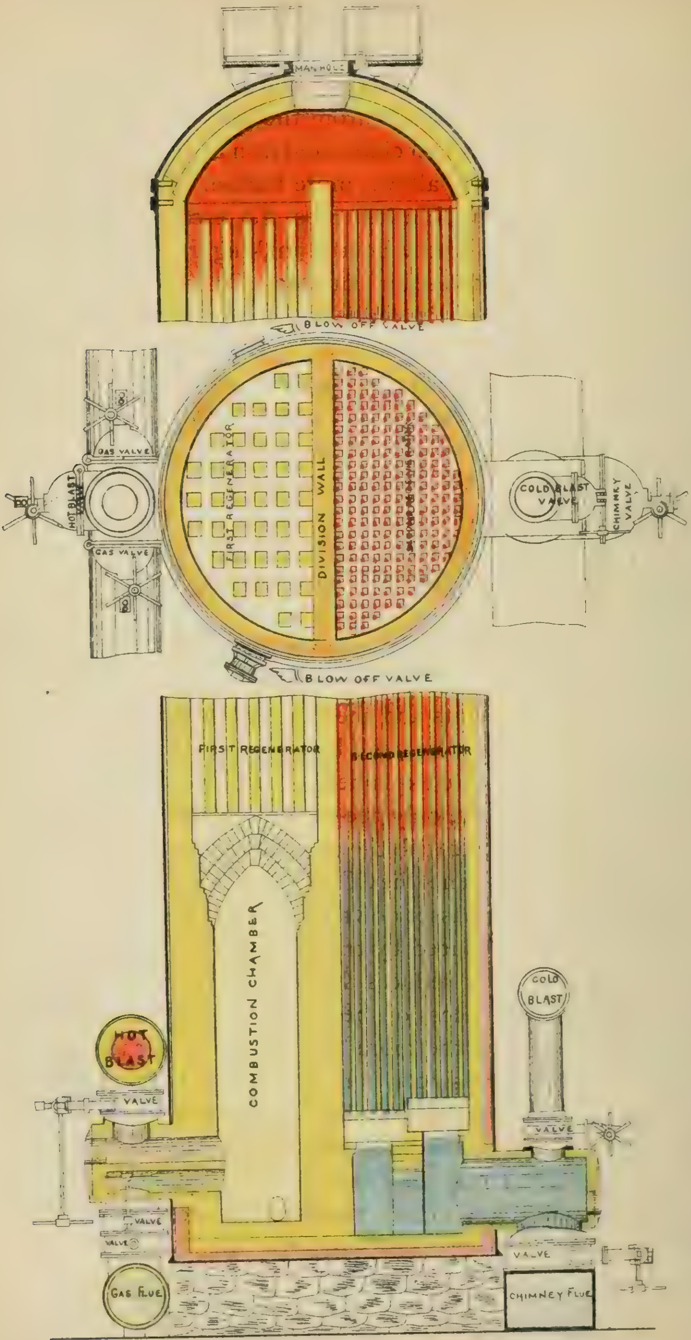

MAN HOLE
BLOW OFF VALVE
GAS VALVE
HOT BLAST VALVE
GAS VALVE
FIRST REGENERATOR
DIVISION WALL
COLD BLAST VALVE
CHIMNEY VALVE
BLOW OFF VALVE
FIRST REGENERATOR
SECOND REGENERATOR
COMBUSTION CHAMBER
HOT BLAST
VALVE
COLD BLAST
VALVE
VALVE
VALVE
VALVE
GAS FLUE
CHIMNEY FLUE

PLATE II.

requirements being well balanced, the hearth is kept hot and the furnace works well. The heat that is conducted off through the foundations, crucible, bosh, shell of furnace and by waste tuyeres water is a constant sum, no matter whether the furnace makes a large or small yield. The faster the furnace is driven the hotter the hearth becomes, as the loss from the above cause is decreased in ratio to the amount of fuel cinder and iron arriving at the tuyeres and in the hearth. This allows more burden to be carried and at the same time this extra burden robs the escaping gas of more heat which is returned to the hearth, making it hotter and allowing a still further increase of burden. This cold top working favors the accumulation of cyanides, which is another economical factor to be explained hereafter.

With a furnace in normal working, it requires about one-sixth of the fuel to supply the heat lost through foundations, etc., as above explained. Taking advantage of all the little points above mentioned, and working them together as a whole, the highest type of furnace economy is attained.

A cold top and hot bottom is economy, large product and good quality. A hot top and cold bottom is waste of fuel, small product and poor quality.

Plate IV, as before stated, shows the effects of a light burden in the interior of the furnace. The amount of heat generated is in excess of its requirements and the heat gradually works up to the top. This partially corrects itself by burning off to waste part of the fuel at the top as before explained. In this case, the ores arriving in the high heat quickly, only the outside of the lumps are deoxidized when the oxide fuses with the gangue and covers the lump with a pasty coating that prevents the CO from reaching the oxygen in the interior. This ore then passes down until it reaches a heat sufficient to melt it when it is reduced by trickling down over the surface of the glowing coal, which reduces the oxygen by contact with solid fuel, forming CO with a loss of heat and making an iron high in silicon, as the more fuel the more silica there is per ton of iron in the fuel, from which the silicon is mostly derived.

To prevent this reduction of silica as much as possible with a light burden the heat in the blast has to be lowered.

Iron from a light burden is light colored, small grain, weak, but runs fluid and makes good stove castings, but costing more than

it is worth, the founder tries to get on a heavy burden and make better and cheaper iron.

When a furnace has been in blast a month, and has been worked up to full capacity, it will assume the shape given by dotted lines on drawing, *Plate III.* Starting from the tuyeres, we find, at a point just above them, that the walls are burned back, and that from there upward they are nearly uniform, until a point a short distance above the bosh is reached, when the walls are found the original thickness. This burning away is due to the intense heat. At this point, the rough, fretted surface of the walls suddenly disappear, and the walls are smooth from the wear of stock. This line between the smooth and rough surface marks the limit of the zone of fusion, and its height is determined by the volume of air entering the furnace per minute. The number of cubic feet of air entering per minute divided by five will give the cubic contents of the zone from the top of fusion limit down to the tuyeres for charcoal; divided by four, will give the cubic contents for coke, and divided by three, the cubic contents for anthracite. These figures have been determined by measuring the area spoken of and comparing it with the air entering per minute in a number of furnaces, and, for all practical purposes, it will be found correct.

Heretofore furnaces have been built with small hearths, thick walls and 80° to 85° boshes. On starting up, the size of the hearth limits the volume of air blown and the zone of fusion is found part way up on the bosh.

If sufficient heat gets above the fusion limit of a blast furnace to paste the stock and yet not fuse it, this stock jams on the bosh, as per *Plate V* forming a ring which, if the stock above cannot push it down to the fusion limit, becomes permanently set and obstructs the flow of stock. If the materials in the stock passed abruptly from the solid to the fluid state, as ice does to water, this condition of affairs could not arise, but we may rather compare the stock to wax, which, when the heat is just insufficient to melt it, becomes pasty and can then be moulded and compressed. The circumference of a furnace of twenty feet bosh is sixty-three feet, while the circumference below at the fusion limit is about forty-four feet. The stock immediately on the bosh and sliding down as a whole is about thirty inches thick, while the balance of the stock in the central portion travels independently and much more rapidly. A

compression or squeezing together of 63 — 44 = 19 feet has to take place in the stock travelling down the slope of the bosh. If the stock is pasty, it squeezes together and jams as above described. This ring or "skew-back" lodges the stock above it up to the top of the furnace (see *Plate V*). The stock descending through the middle of the furnace by its side thrust retains this lodged stock in a vertical position, making a dry wall of it. This cuts off the reducing area of the furnace and proves Cochran's law—that the yield of a furnace shows its working area.

The founder would then draw back his tuyeres, enlarge the hearth by allowing it to cut away with a larger volume of blast. This cuts away the circular ring or scaffold and allows it to come down to the tuyeres. When there was ample fuel below the scaffold from fuel blanks previously charged to meet it, the furnace would pull through all right, but, if the coal were burned away, the scaffold would chill the zone of combustion and the furnace would have to be shovelled out.

Instances have been found where a furnace 16-foot bosh, 65 feet high, had a vertical well perfectly round, 6 feet diameter, extending from 7 feet above the tuyeres to the top. The sides of the well were about 12 inches thick, composed of the fuel ore and limestone partly fused together. Between this wall and the in-walls of the furnace the stock laid loose and in good condition.

When this lodgment or scaffold occurs, the lodged part collects heat at the bottom, which accumulates and works up through it to the top of the furnace. The stock lodged against the walls under the bell becomes red hot, while the moving stock in the centre is cold. This has led to the idea that a furnace sometimes works up its walls, while the reverse is the case.

If a furnace has been in this condition for some time, the attrition of the stock and an increase of temperature sufficient to partly melt off the skew-back, sometimes causes the latter to give way slowly, and the scaffold gradually slides downward in the furnace leaving a ring adhering to the bosh. While the furnace is melting and burning up the lodged part, it becomes extremely hot, as the work of reduction has been done thoroughly and carbon is stored up in the part of the scaffold above the skew-back, where no oxygen or CO^2 can reach it. The founder in this case increases the burden and drives the furnace. As soon as this lodged part is

worked out, the furnace turns on white iron, unless the founder has reserve heat in the hot blast. When a furnace in this scaffolded condition is blown down, the dry wall around the sides falls in and no trace of it can be found. When the founder gets the furnace blown down to the bosh and finds no scaffold, he refills; but the first time slack blast is used, the skew-back builds up again and on putting on full blast the furnace makes white iron and the old trouble shows itself. From the foregoing explanations, it will be seen that the difficulty is that he did not blow it down to this ring or skew-back.*

Furnaces built the old shape, as per *Plates 5* and *6*, cut out so much at and above the tuyeres, that the engine and hot blast are not large enough to supply blast to fill this space, and the blast shuffles about from side to side of the furnace, causing it to work hot first on one side and then on the other. As the heat cannot be concentrated, white iron results. The furnace must then be blown out and a new bosh put in.

The difficulties of the old form of furnace may be avoided by adopting the form shown in *Plate III*, using a large hearth, with the proper volume of air, and placing the bosh far enough below the fusion limit to avoid the danger of the jamming of the stock on the bosh. Any pastiness of stock will occur between vertical walls, the heat will be concentrated and the blast equalized, across the tuyere section. As the upper part is simply a hopper to hold the stock during reduction, its shape will be immaterial so long as the charging apparatus can distribute the stock evenly.

If the furnace works irregular, the founder will often lay the blame on the bell and change it, thinking a smaller bell will do better, as the stock is high on the walls, but he has not discovered the fact of a ring scaffold causing the furnace to work up through the centre,

---

* The fuel, ore and limestone above the fused part of the ring scaffold disintegrate to a gravel and dust, which, when the ring gives way, (more or less) roll down to the tuyeres and smother the coal in the zone of combustion. The fine fuel would burn readily if the blast could penetrate it. In some few cases where the engines could blow twenty pounds to the inch pressure, they succeeded in blowing through the gravel and dust. The better plan is to take out the tuyeres and shovel it out before it fuses, sets and chills the hearth. Fifteen cart loads have been taken from a single furnace before the bright fresh coal got down to the tuyeres. A vigorous policy in blowing will stop this trouble.

and not on the sides. Let the bell alone as long as it is about one-half the bosh in diameter.

Pyrometers should be placed in the sides of the furnace above the bosh and one in the escaping flue, that the working of the furnace may be controlled in case the equilibrium is disturbed by the encroachment of one zone on another by any excess or decrease of heat. To establish and maintain this equilibrium is the work of the future. A furnace built as described will retain its shape and take a certain uniform volume of blast, as the contents of the zones of combustion and reduction will bear a fixed relation to one another. With reserve power in the stoves to correct any loss of heat, a burden of ore can then be determined upon for a given grade of iron that needs no changing, as by varying the heat of the blast to make up any deficiency or excess of heat, iron of the required quality can be always produced.

Furnaces are now built with their bosh walls well bound, water cooled, for an emergency, large hearths and blown with large volumes of blast, through short bronze tuyeres. Large hearths mean business, they must have the proper volume of hot blast and have it well distributed. To get the proper penetration and distribution of blast, the nozzles of tuyeres must be proportioned to the volume of entering air. When they are too large, the blast works up the walls, destroying them and leaving the stock in the centre to form a core. The blast then forms pockets in front of tuyeres and on slacking blast the cinder runs back in the tuyere pipe, as the cinder has no free passage to the cinder notch. To prevent this, small cinder notches are now placed under each tuyere. If too small nozzles are used, the stock on the walls settles slow by the friction and eventually forms a skew-back while the stock above is held back, forming a scaffold. When this occurs, the furnace falls off in yield.

Perfect success with the furnace depends on clean bosh walls, and the stock travelling evenly on the walls and in the centre. There must be no skew-backs on the bosh, and the blast must so penetrate that the fuel column will burn across at the tuyeres, allowing the furnace to settle evenly. But few furnaces are free from scaffolds, and it is rare to find a founder who is willing to admit he has one.

Again, if the nozzles are too large and the furnace should ease up on one side, all the blast will pass up that side, checking the

descent of the stock on the opposite side at and above the zone of fusion. If this is not corrected, the stock will fasten to the walls and form a side scaffold, as per *Plate VI*, which will show at the top by the stock settling on one side. These are the most annoying and troublesome scaffolds, and they can be often detected by their making one side of the furnace shell hot, and on going out of blast a large space will be found cut in the inwalls where the gases were forced past the edge of the scaffold, as in *Plate VI*.

A differential gauge attached to each tuyere pipe shows whether blast is entering all the tuyeres evenly. The heat under a scaffold gradually works up through it, melting out the iron and leaving behind the fuel and lime cemented together by the cinder in a compact mass. This is difficult to burn and fuse, as the blast cannot get at the fuel in it until the cinder and lime disappear. When the volume of blast is increased so that the under side of the scaffold is attacked, the skew-back will loosen more or less, and leave it down to the action of the blast, when, if there is not ample fuel before the tuyere to work it up, the zone of combustion is chilled and the furnace goes out.

The iron and cinder melting out of a scaffold is caught by the slope of the bosh, and grooves are worn in it by this running iron and cinder. If one of these grooves directs the iron and cinder on the nose of a tuyere, it destroys it, leaving water in the crucible and destroying the heat just at the time it is most wanted.

The quickest way to get rid of these scaffolds is to have a series of holes in the bosh and side walls where they are likely to form, and crack them off with giant powder, but the precaution must be taken to have some extra fuel down to the hearth to melt them up and prevent chilling. When any trouble occurs with a scaffold, the hearth generally fills up with mucky cinder, coal and iron. The iron notch should then be used exclusively to take off the cinder and iron, and if this does not clear the hearth then cut another iron notch in the crucible at hearth line opposite the regular iron notch, leaving the cinder and iron flow out there. This will heat up hearth and keep tuyeres clear of cinder. Tuyeres must be kept clear or the furnace goes out.

Heretofore, there has been a horror or dread of cutting a hole in the furnace, but this must not stand in the way of helping the furnace. A furnace with the cinder notch placed opposite the iron notch always works more evenly than with both on the same side.

When a furnace works irregularly, some tuyeres are bright, some are dark; if the belly pipe is cold no blast is entering at that tuyere and it must be opened at once by the pricker rod, or by a small cartridge exploded just beyond the tuyere, circulation must be had at once. A bright tuyere and cold belly pipe shows but little circulation. The differential gauges are the best things to rely on in this case. A constant half hourly inspection of the tuyeres must be continually made to see that no water gets in the hearth.

With a large hearth and the proper time for reduction, the faster a furnace is driven the hotter she becomes, more burden is carried, more iron made, and more steady is her working, until the limit of the volume of blast for the hearth is reached, when no further advance can be made without cooling the hearth, as the rate of combustion is limited by the size of the hearth. With a given hearth, more blast can be used at 1,400° than at 900°.

A serious evil with furnaces is a stoppage, as it always gives more or less trouble by forming incipient scaffolds. For each minute that blast is off, a furnace making 700 tons per week, 156 pounds of iron are lost. Leakage of blast is another evil to be carefully guarded against. Even with a new plant, well built, there is a loss of twenty-five per cent. of the volume when blowing ten pounds to the square inch. The volume of air that passes the tuyeres is what does the work, and not the volume that is blown by the engine. Instances have been found where the engine running twenty-four revolutions, on blanking all the tuyeres tight, the engine run sixteen revolutions on the leaks.

In addition to the difficulties mentioned of the running of the furnace, the superintendent has to be continually on the guard against changes in the character and quality of his stock, in neglect or carelessness of his men, especially at night, and in stormy weather to see that the stock is well supplied and kept dry; that freshets do not interfere with the tuyere water, and that the machinery, boilers, stoves, pumps, etc., are kept in good order.

When his furnace is carrying a good burden and a damp spell comes on, he must add fuel to the furnace to keep up his heat, as each 10,000 feet of air per minute will require a ton of coal in twenty-four hours to maintain the equilibrium of heat in the furnace. Good analysis of all stock should be going on constantly

and avoid the stumbling in the dark and the blundering of the past.

Having given a general description of furnaces, let us take up the Franklin Furnace of New York, as shown by *Plate 3*, and its workings for one week.

Hearth 9 feet, bosh 14 feet, height 70 feet, stock line 11 feet, bell 6 feet 6 inches, bosh walls 18 inches thick on slope, and 14 inches above the slope, and the mantel placed above the top of bosh. Crucible bound with cast iron water jacket. Bosh bound with heavy boiler plate jacket. Fire brick stoves.

ONE WEEK'S WORK.

Fuel per ton pig sixty-three and one-half per cent. coke, thirty-six and one-half per cent. anthracite,	2,538 pounds.
Ore per ton hematite fossiliferous,	5,091 "
Limestone,	1,426 "
Volume blast per minute in cubic feet,	13,514 "
Temperature of blast,	1,100°
Temperature of escaping gas,	210°
Iron,	614 tons.
Cinder per ton of pig iron,	2,474 "
Cubic contents of furnace in feet,	6,731
Air per minute, per 1,000 cubic feet of contents in feet,	2,000
Ratio of escaping gas by weight $\frac{CO^2}{CO}$	.938

Grade of iron, 342 tons No. 1, 260 tons No. 2, 12 tons No. 3.

ANALYSES OF ORE AND CINDER.

	Iron.	*Silica*	*Alumina.*	*Lime.*	*Magnesia.*	*Carbonic Acid.*	*Water.*	*Oxygen.*
Ore,	44·00	12·20	5·04	6·30	3·30	6·20	4·10	18·86
						Sulphur.	*Oxide of Iron.*	
Cinder,		35·98	11·80	43·67	6·38	1·12	1·02	

The ore is composed principally of small grains or shots of hematite, resembling shad eggs. This rapidly disintegrates in the furnace, leaving the CO act quickly, and as the ore contains some CO^2 this is easily expelled, leaving the ore absorb carbon quickly.

HEAT CALCULATIONS.

	Calories.
Total heat generated per ton of iron,	18,051,819
" " absorbed " "	15,661,716
Loss by radiation tuyere water, gas at top, blowing out, etc.,	2,390,103

No allowance is made for loss in expansion of blast, as this is a fallacy in the English calculations of Bell. A pound of air expanding does not lose weight and consequently cannot lose heat unless it does work. It has simply changed its quality but not its quantity. The above loss is 13·2 per cent., a gain of twenty-two per cent. in calculations of heat loss in the best English furnaces. The rapid rate of driving with heavy burden leaves the escaping gas go off at a remarkably low temperature, and prevents any burning off of the fuel at the top of the furnace by the carbonic acid of the limestone attacking the fuel and forming carbonic oxide. This low temperature of escaping gas favors the accumulation of alkaline cyanides in the furnace, which under the influence of high heat at the bottom of the absorb oxygen rapidly, and then escape upward where they part with their oxygen, are condensed on the cold down coming stock and carried down to the bosh to perform again their office of reduction, and save fuel. These cyanides are formed from minute traces of potash and soda occurring in the coke or coal, and which, being set free in the zone of fusion, escape up, are condensed on the cold stock, and returned down again. This accumulation goes on until a large volume is collected. With charcoal, there is always plenty of potash and soda. When a furnace begins to scaffold below, the stock at top gets hot, leaving the cyanides escape into the flue. If gas washers are used the waste water from washer will give off the fumes that are noticeable by their smell when the tops get hot. This simple test tells beforehand that trouble is coming.

The ratio $\frac{CO^2}{CO}$ by weight is much higher than has been heretofore found. Gas analyses are troublesome and rarely accurate as the furnace does not constantly give off a uniform volume of gas. Taking gas temperatures at the tunnel head they will vary on four points in an hour 200°. In the flue where the gas samples are taken for analyses the heavier gas, carbonic acid, flows along the bottom while the carbonic oxide flows along the top and it is impossible to get an uniform sample. This ratio of $\frac{CO^2}{CO}$ is an index or guide to show furnace men how near the gas is exhausted of its reducing power.

To absorb the last atoms of oxygen from the ores requires a high heat, especially with hard, close-grained ores difficult to

reduce. If they were reduced by CO forming CO^2 the intensely hot iron sponge would split up the CO^2 and burn part of the iron back to the oxide. This fact requires that the last atoms of oxygen must be removed by solid fuel which forms CO.

According to the degree with which reduction is carried on by solid fuel so will the ratio $\frac{CO^2}{CO}$ vary.

If perfect reduction could be made with CO the ratio $\frac{CO^2}{CO}$ would be 1·22.

The nearer we approach that figure, the less is the oxygen of the ore reduced by solid fuel. The oxygen absorbed by CO to CO^2 generates 4,205 calories while oxygen absorbed by solid fuel forming CO gives but 1,855 calories. The more oxygen absorbed by CO the more is the heat produced and the heavier is the burden that can be carried.

The less fuel burned to CO by the oxygen of the ores, the more fuel escapes to the tuyere to make CO and heat which in its turn allows more burden to be carried.

With analyses of fuel, ore and stone, gas analyses can be dispensed with by making the following calculations. Taking data from the charge book of any furnace for one week, say:

CO.	Tons.	CO^2.	Tons.
Carbon in fuel (less carbon in pig) to CO., say,	5,094	CO^2 in stone, say,	560
Deduct CO to reduce ore, say,	1,680	O in ore reduced to CO^2, say,	963
		CO reduced by ore to CO^2, say,	1,680
	CO = 3,414		CO^2 = 3,203

$$\frac{3{,}203\ CO^2}{3{,}414\ CO} \cdot 938.$$

Mr. Bell gives the best English workings at ·70, and instances have been been found at ·76. The best American practice previous to this has been ·72.

No carbon, except that in the pig, can escape the furnace except as CO or CO^2; if fuel burns off at the top, it goes off as CO, leaving that much less to burn to CO at bottom, so that the result is the same in the gas in the flues whether it burns at top or bottom. Much has been said about English workings using less than a ton of fuel to a ton of iron. While this is true, yet they have calcined carbonates, with part of the work already done, higher furnaces, and a coke that contains six per cent. more car-

bon than ours, and which will carry twelve per cent. more burden. Our ores are more siliceous and require more limestone, whose carbonic acid weakens the action of the carbonic oxide in reducing the ores, which, in its turn, to make proper reduction, requires more fuel.

At the present time, at Woodside Furnaces, in England, they are calcining the limestone, using it direct from the kilns, and find a good saving in fuel in the furnace, as the carbonic acid driven off in the kilns does not dilute the reducing gas.

By the use of rich sixty-three per cent. ores, high heat in blast, and but 608 pounds limestone to the ton of iron, American furnaces have got their fuel down to 2,020 pounds, with $\frac{CO^2}{CO}$ ·73, and escaping gas, 480°.

The limit of heat fixed by Mr. Bell in English escaping gases has been lowered by our workings beyond his expectations.

Returning to the lines of the Franklin Furnace, it will be seen that the zone of fusion is above the bosh and the bosh is below the mantel. This prevents any partly fused material touching the bosh, as all the ore and stone disappear above it, leaving nothing but the fuel to slide down the bosh, thereby preventing any accumulation on the bosh, and keeping the bosh walls perfectly clean. No water has so far been used on the bosh jacket and no signs of heat are exhibited about it. The ores are oolitic fossiliferous hematite, that disintegrate and reduce readily. This is one reason why this furnace will use so much more air per 1,000 cubic feet of contents than is usually found.

Since making the 614 tons here noted, the furnace has made 692 tons per week on the same mixture, using 14,000 feet of air per minute. Twelve years ago this furnace ten feet lower, made 156 tons per week, using the same ores—stone and fuel, but by the addition of powerful engines, boilers, and large fire-brick stoves, with an active, intelligent management, their present success has been obtained and will continue.

Turning to the Isabella Furnaces at Pittsburg, it will be found eleven years ago they averaged 578 tons per week on 7 feet 6 inch hearth, 20 feet bosh 75 feet high, to-day, with more engines and large fire-brick stoves, they are averaging 1,200 tons, while at the Lucy Furnaces 1,825 tons were made in one week on a spurt.

Heretofore, young men have kept out of furnace business, as it is a dusty, dirty, hard, brain-working trade, requiring twenty-four hours a day of constant care, 365 days a year, and as a blast usually lasts about 1,000 days, he has but little chance for a genuine holiday.

Much is yet to be learned to always operate a furnace successfully, but the day is coming when it will be run with all the precision of a Bessemer converter.

NOTE.—Mr. James Gayley, Supt. of Furnaces at Edgar Thomson Steel Works, writes, "Our furnace 'D' for week ending April 3, 1886, made 1,529 tons of No. 1 Bessemer iron, using 1,993 pounds of coke (including waste) with 65 per cent. ores and 851 pounds limestone per ton of iron."

THE NEW STAR IN ANDROMEDA.—Of all the thousands of nebulæ now known to astronomers, the Great Nebula in Andromeda is the only one, the discovery of which preceded the invention of the telescope. It was also the first upon which the telescope was turned, and it has now been a subject of observation for nearly 300 years. Yet, as a recent astronomical writer has remarked, "We are hardly more advanced than we were two centuries ago, as to the explanation of this immense nebula. Whilst, among those discovered since, some have been resolved into clusters of stars, and others have proved their chemical constitution to be of a gaseous nature, this has remained silent and mysterious. Its spectrum is continuous, without transversal lines, and consequently the substances which compose it remain unknown. The highest powers have shown some 1,500 stars in it, but it is not certain that these stars belong to it; they may simply be before it. Its shape alters strangely according to the power employed." It is premature, no doubt, to attempt to draw any very definite deductions from the present outburst; but it should always be clearly borne in mind that these "temporary" stars—this one is already fading—cannot be stars in the least resembling our own sun in size or structure. Could the radiations of our sun be suddenly increased a thousandfold, it could not possibly resume its former scale of brightness within the course of a few weeks or months. The suddenness of the increase and subsequent decrease of light prove unmistakably that we have to do with bodies relatively minute, and therefore capable of rapid cooling. The only alternative—that the star has not really altered its lustre, but that some intervening screen has been temporarily withdrawn—seems inadmissable, especially in view of the spectroscopic history of T. Coronæ and Nova Cygni. Since, then, the distance of these stars is so great (as yet an appreciable parallax has not been obtained for any one of them) and their brilliancy so high, we are compelled to substitute for a compact sun a loosely scattered, widely extending system of small bodies—a system similar in character, but on an indefinitely larger scale, to that which we see in the corona or in the rings of Saturn.—*The Observatory, October, 1885.*

HYDROGRAPHIC WORK OF THE UNITED STATES NAVY.*

By Lieut. A. B. Wyckoff, U. S. N.

[*A Lecture delivered before the* Franklin Institute, *February 19, 1886.*]

After the conclusion of the Revolutionary War, the officers of the few national vessels then in existence, were employed, as opportunity offered, in the survey of the waters of our coasts. In 1807, the President was authorized by Congress to have a survey of the coast of the United States made, and cause to be employed as many of the officers of the Navy, on the hydrography, as was compatible with the successful prosecution of the work. Under this law, and succeeding ones of the same tenor, the officers of the Navy, in times of peace, have accomplished the hydrographic survey of nearly the whole of our coasts. The resultant charts, published by the coast survey, are the finest in the world. Any careful navigator, who has them, can enter any of our principal ports with safety, without the assistance of a pilot. The officers of the Navy attached to the Coast Survey, have not been confined strictly to surveying. They have developed the beds of the Gulf of Mexico, Caribbean Sea, and Atlantic and Pacific Ocean for a considerable distance from our shores; and have spent much time and labor in the study of the Gulf Stream and the physical problems of the waters contiguous to our coasts. A present distinguished resident of this city, Rear Admiral Mullaney, spent four years in the brig "*Washington*" at this work. In July, 1885, there were sixty-seven naval officers actively employed in the Coast Survey.

The triangulation and topography of the coast line has been mostly done by civilian assistants in the Coast Survey. Their accurate scientific work is acknowledged the world over.

The vessels of our Navy have always made surveys of unknown localities abroad, whenever opportunity offered. In fact, it is one of the most important duties of our national vessels when cruising.

* This Lecture does not pretend to enter into the minute details of the scientific methods used in surveying, and was only written with the object of conveying some idea of the hydrographic work being accomplished by the United States Navy. A. B. W.

They are constantly doing a great deal of this work, as I can testify from personal experience. At different times, many men-of-war have been fitted out and sent upon special surveying cruises. In 1838, the Wilkes Expedition, consisting of several vessels, was sent to survey the South and North Pacific Oceans. During the next five years a vast amount of surveying was done, and large collections of scientific data made. The knowledge gained of the islands and coasts explored, has been of great value to commerce and the world. In 1853, a similar expedition was sent to the East Indies, under the command of the late Rear Admiral John Rodgers. It spent three years in the then little known waters of China and Japan. The commands of Page, Perry and other naval officers also did a great deal of hydrographic work.

As the result of these expeditions, 112 charts were published, besides many volumes of sailing directions and other useful knowledge.

The grand work of Lieut. Maury is probably familiar to you all. While stationed at the Naval Observatory, he was fortunate in arousing the interest and securing the assistance of all civilized maritime countries; and as the result of the observations on national vessels, and by intelligent masters of ships in the merchant service, gathered an immense amount of valuable data. This was collated and published in his sailing directions and wind and current charts. Only a seaman can fully appreciate the great importance of these publications. Ship captains were wholly guided by them, and in a few years Lieut. Maury showed, from actual data collected, that the voyage from New York to Rio Janeiro had been shortened from forty-one to thirty-four days, to San Francisco from 180 to 128 days, and to Australia from 127 to ninety-five days. These are simply taken as illustrations, as voyages between many other ports were equally reduced. When we consider the immense tonnage afloat in sailing vessels, the saving to commerce by the shortening of passages, as the result of Lieut. Maury's researches, must have amounted to many millions annually.

In 1866, Congress established the Hydrographic Office, and attached it to the Bureau of Navigation, Navy Department. Several eminent naval officers have had charge of it at different times. The present hydrographer, Commander J. R. Bartlett, U. S. N., took charge of it in 1883; and has thoroughly reorganized it, and extended its usefulness in many ways.

The law of Congress authorized the sale of the hydrographic publications at the actual cost of the printing and paper. In consequence, our charts are sold at very low prices as compared with those of foreign countries. In 1885, over 22,000 charts were printed at the Hydrographic Office. In order to preserve the original copper plates, they are now electrotyped, an alto and basso produced, and the charts printed from the latter. About 900 different charts are published, while several hundred more are issued by the Coast Survey, and 3,000 by the British Admiralty. These sheets cover the surveyed waters of the globe.

When a new rock or shoal is discovered in any part of the world, or a new buoy is placed, or light established, a notice is at once sent to our Hydrographic Office. In 1885, 2,130 of these notices, in ten different languages, were received. They were immediately translated, republished, and forwarded, with the notices of our own coasts, to our Consuls abroad, the principal newspapers, custom-houses, maritime exchanges, branch hydrographic offices, etc.

Thus the master of a vessel, about to leave port, can thoroughly post himself regarding all changes which are likely in any way to affect his voyage. The neglect of this precaution, led a consular court to severely censure a master, who came in the Capes of the Delaware recently, and lost his vessel on the shoals. Each one of these notices to mariners necessitates the correction of all the charts and sailing directions which they affect.

There is also a meteorological division of the Hydrographic Office, where the data received from our national vessels and voluntary observers in the merchant marine, are carefully collated and prepared for publication. The amount of meteorological information collected by our men-of-war, is very great. About fifty national vessels, in all parts of the world, keep extensive log books, and the data is perfectly reliable as the result of most careful observations by experienced men. The following are the data noted every hour:

LOG OF THE UNITED STATES SHIP "*PORTSMOUTH.*"

Hour.	Knots.	Tenths.	Courses steered.	Winds. Direction.	Winds. Force.	Leeway.	Barometer. Height in Inches.	Barometer. Thermometer attached.	Temperature. Air, Dry Bulb.	Temperature. Air, Wet Bulb.	Temperature. Water at Surface.	State of Weather by Symbols.	Forms of Clouds by Symbols.	Proportion of Clear Sky in Tenths.	State of the Sea.	Record of Sail Vessel was under End of Watch.
A. M.						Pts.										
1	7	0	N. N. E.	N. W.	4	½	30·14	58	58	54	60	b. c. q.	cu. nimb.	3	H.	Single reefed topsails, fore topmast staysail and courses.
2	6	4	"	"	4-5	"	30·12	59	59	55	60	"	"	4	"	
3	6	6	"	"	5	"	30·11	60	60	56	60	"	"	4	"	
4	7	0	N. E.	W. N. W.	6	¼	30·07	62	62	57	59	"	"	3	R	
5	7	4	"	"	5–6	"	30·04	62	62	58	60	b. c.	"	2	"	
6	7	6	N. E. ½ E.	"	6–7	"	30·00	63	63	58	60	o. c. q. r.	nimb.	0	"	

Distance run by Log since preceding Noon, ...	knots	tenths.
Latitude by D. R. at Noon, ...	°	′ ″
Longitude by D. R. at Noon, ...	°	′ ″
Latitude by Observation at Noon, ...	°	′ ″
Longitude by Chronometer by Forenoon Observations, ...	°	′ ″
Current, ...	knots	tenths.
Variation of the Compass by Amplitude, ...	°	′
Variation of the Compass by Azimuth, ...	°	′

FORM B.

(FOR METEOROLOGICAL DATA.)

HYDROGRAPHIC OFFICE, METEOROLOGICAL DEPARTMENT.

Limit of Square.

Latitude, 35° N. to 40° N.; Longitude, 130° W. to 135° W.

Date ship was in this square, January 22 and 23, 1876.

Compiled from the log book of the U. S. S. ——.

Commencing January 1, 1876, and ending June 30, 1876.

No. of Hours.	Magnetic Direction of Wind.	Mean Force.	No. of Hours.	Magnetic Direction of Wind.	Mean Force.	No. of Hours.	Magnetic Direction of Wind.	Mean Force.	No. of Hours.	M Dir
	N.			E.			S.		2	
	N. by E.			E. by S.			S. by W.			W
	N. N. E.			E S. E.			S. S. W.			W
	N. E. by N.			S E. by E.			S. W. by S.			N.
	N. E.			S. E.			S. W.		9	
	N. E. by E.			S. E. by S.			S. W. by W.		13	N.
	E. N. E.		2	S S. E.	1	1	W. S. W.	6	12	N
	E. by N.			S. by E.		2	W. by S.	7	1	N

Mercurial Barometer		Fahrenheit's Thermometer.						No. H
		Dry Bulb.		Wet Bulb.		Sea W. at Surf.		
Mean.	Daily Range.	Mean.	Daily Range.	Mean.	Daily Range.	Mean.	Daily Range.	Heavy.
29·91	0·26	56·4°	4·5°	52·4°	8°	60·6°	1°	13

FORM B.

(FOR METEOROLOGICAL DATA.)

HYDROGRAPHIC OFFICE, METEOROLOGICAL DEPARTMENT.

Limit of Square.

Latitude, 35° N. to 40° N.; Longitude, 130° W. to 135° W.

Date ship was in this square, January 22 and 23, 1876.

Compiled from the log book of the U. S. S. ———.

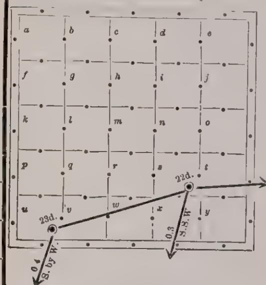
Commencing January 1, 1876, and ending June 30, 1876.

No. of Hours.	Magnetic Direction of Wind.	Mean Force.	No. of Hours.	Magnetic Direction of Wind.	Mean Force.	No. of Hours.	Magnetic Direction of Wind.	Mean Force.	No. of Hours.	Magnetic Direction of Wind.	Mean Force.
	N.			E.			S.		2	W.	7
	N. by E.			E. by S.			S. by W.			W. by N.	
	N. N. E.			E. S. E.			S. S. W.			W. N. W.	
	N. E. by N.			S. E. by E.			S. W. by S.			N. W. by W.	
	N. E.			S. E.			S. W.		9	N. W.	5
	N. E. by E.			S. E. by S.			S. W. by W.		13	N. W. by N.	6
	E. N. E.		2	S. S. E.	1	1	W. S. W.	6	12	N. N. W.	7
	E. by N.			S. by E.		2	W. by S.	7	1	N. by W.	7

Mercurial Barometer		Fahrenheit's Thermometer.						No. Hours Squalls.		
		Dry Bulb.		Wet Bulb.		Sea W. at Surf.				
Mean.	Daily Range.	Mean.	Daily Range.	Mean.	Daily Range.	Mean.	Daily Range.	Heavy.	Moderate.	Light.
29·91	0·26	56·4°	4·5°	52·4°	8°	60·6°	1°	13	19	

Square No.	No. of Hours in Square.
28	40

SHIP'S TRACK THROUGH SQUARE.



NO. OF HOURS OF—

Var. Wind.	Calm.	Fog.	Rain or Mist.
			22

WEATHER BY SYMBOLS.

b. c. oc. p. q r. d. h.

Forms of Clouds.	Clear sky.
Cu. nimb.	2

MAG. VAR. IN—

Lat.	Long.	Lat.	Long.
35° 2′	134° 30′	35° 59′	131° 36′
15° E.		14° 30′ E.	

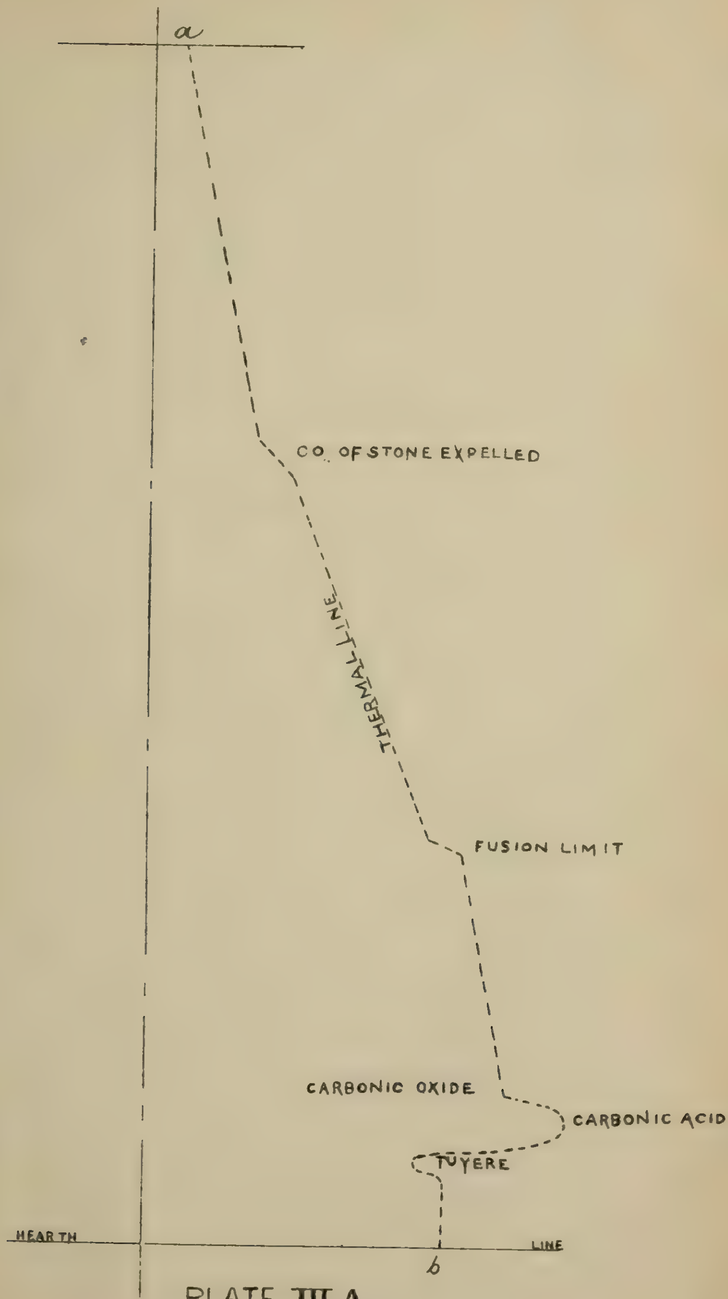

a
CO. OF STONE EXPELLED
THERMAL LINE
FUSION LIMIT
CARBONIC OXIDE
CARBONIC ACID
TUYERE
HEARTH
LINE
b

PLATE III A.

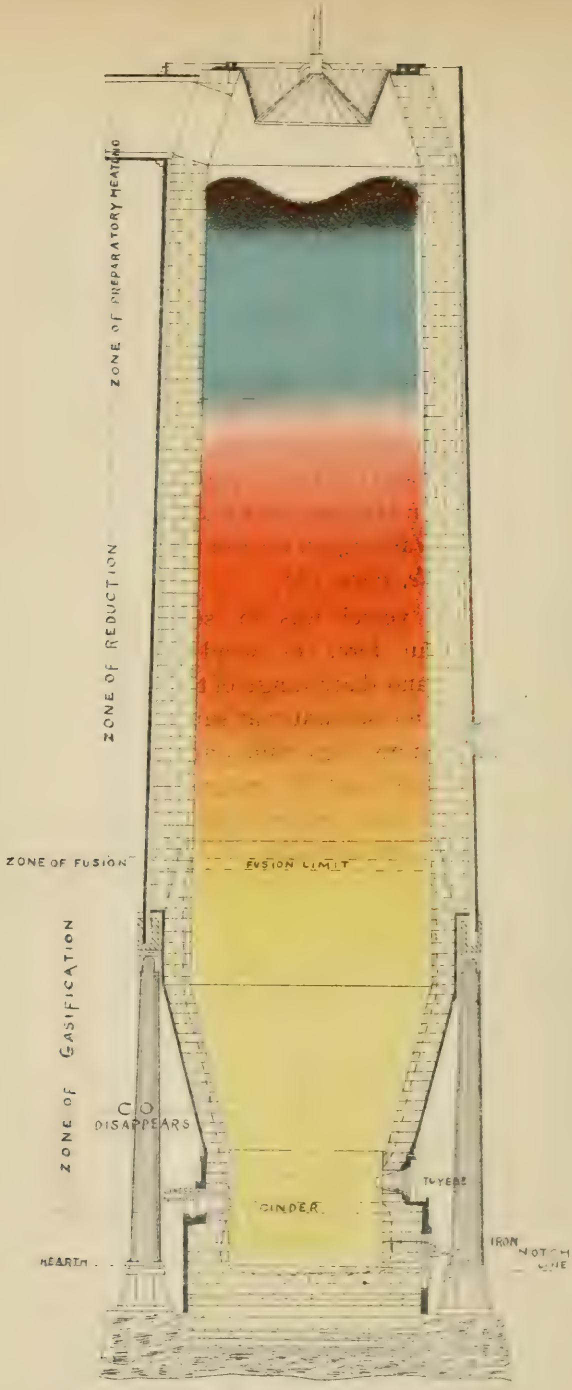

ZONE OF PREPARATORY HEATING
ZONE OF REDUCTION
ZONE OF FUSION
FUSION LIMIT
ZONE OF GASIFICATION
CO
DISAPPEARS
TUYERE
CINDER
IRON
NOTCH
HEARTH

PLATE III.

Afternoon sights are also taken, and a great many other observations of the stars, moon, etc., are frequently made. In addition to the above, the Officer of the Deck writes up his remarks, which describe the wind and weather more fully, and notes everything of interest that has occurred ; such as height and character of waves, description of peculiar clouds, meteors, water-spouts, etc. The density of the sea water is also taken at least once in each watch of four hours.

These log books are stored in Washington for future use. In order to have the meteorological data in shape for reference, the navigator is furnished with a chart, on which the navigable waters of the earth are divided into five degree squares, with a distinctive number for each. After making a passage, he carefully calculates the time when he entered and left each square. The data for each square are then collated, and entered on a blank form similar to the following, and is sent to Washington for use in compiling meteorological charts : (*See Table, Form B.*)

It is seen that the vessel was in square 28, 40 hours. The direction and mean force of wind is given for that time. The mean height and daily range of the barometer, wet and dry bulb thermometer, and sea water at surface ; the number of hours of variable w ıs, calms, fogs, rain, and clear sky ; the forms of clouds weather symbols, and the magnetic variation are all entered. In the small square to the right is shown the vessel's track, and the direction and strength of current. Appropriate remarks are appended on the form, describing the sea and weather experienced.

If the vessel should meet with a storm or cyclone, the navigator fills out a form similar to the following :

Hours.	Knots.	Courses.	Winds.	Force.	Leeway.	Mer. Bar. inches.	D. B.	W. B.	Weather.	Clouds.	Clear Sky.	Sea.
8	13	S.	S. E.	6–8	4 pts.	29·79–29·72	83	80	o. c. r.	Nimbus	o	L.
10	12	S.	S. E. by S.	7	"	29·72–58·	83	80	"	"	"	"
8	13	S. S W.	S. by E.	9	"	29·58–10·	81	79	o. q. l. r.	"	"	R.
10	13	S. W.	S. by W.	10–11	6 pts.	29·10–28·70	80	78	"	"	"	"
4	5	W.	S. W.	5–8	4 pts.	28·70–29·40	81	79	"	'	"	"

The basis of arrangement of the above form is, the changes of the wind. Remarks are added, giving a full history of the storm.

The navigator also keeps the international simultaneous meteorological observations, in which all particulars of the weather are given at 4 hrs., 8 m., A. M., 12 hrs., 8 m., and 8 hrs., 8 m., P. M., G. M. T., and the latitude and longitude of each observation.

The navigator's duties do not end with the preceding. When he enters a port, he must carefully examine his charts and sailing directions and note any changes. He must report upon the pilot, harbor and custom laws, marine signals, time signals, commerce, climate, astronomical observations, etc. When in strange waters, soundings are taken and carefully plotted; and the appearance of islands, headlands and all prominent land-marks are fully described. Some of our vessels are fitted with deep sea-sounding apparatus, and it is proposed to have them on all men-of-war, and take the depth of water, every twenty miles when making passages. Many lines of deep sea-soundings have already been run, in the Atlantic, Pacific and Indian Oceans, by the "*Narragansett*," "*Tuscarora*," "*Enterprise*," "*Gettysburg*," and other naval vessels.

Several of our men-of-war have also been provided with instruments for observations of the terrestrial magnetism, and have done much good work of this kind in foreign countries.

When a navigator enters a strange harbor, of which there is no good chart, if time allows, he is ordered to survey it. His only instruments are, usually, sextants, chronometers, compasses, a steel tape and lead lines. With these, however, a very good survey can be made. If he has good chronometers, recently rated, he can establish very accurately, the latitude and longitude of some spot near his base. Then, with his steel tape, he carefully measures his base line several times, along the level beach or some level piece of ground. The direction of his base line is accurately established by astronomical bearings. Small flags are then placed in suitable positions, around the shore line of the harbor, and the nearer ones are cut in from both ends of the base line. The signals are successively occupied, and rounds of angles taken upon the others in view. The fact that the angles of the different triangles must close within a few seconds; that is, add up 360°, is an efficient check upon the work. A permanent mark, usually a stone with a cross

cut in it, is buried at each end of the base line, and such reference is made in the notes to surrounding natural objects, as to lead to future recovery. Some prominent mark is also usually erected at the observation spot.

A large scale is adopted for a small harbor, and the base line is carefully plotted. From it, the signals are cut in upon the sheet, and the compass card constructed. The shore line between the signals is readily run in with a compass and log line, and the topography is roughly sketched. A tide gauge is erected at some spot where it is little exposed, and out of the strong currents. A staff with feet and tenths marked plainly upon it, answers perfectly well in a harbor. A permanent bench mark is erected near, and the distance, direction and height, from the plane of reference on the tide staff, carefully determined. Of course, the tidal observations should extend through one lunar month, if possible, and the plane of reference is the lowest low water. The establishment of the port, and all the tidal elements, can then be entered on the sheet. The hydrography is executed according to some general plan. The one usually adopted is to run parallel lines of soundings across the harbor, and then others perpendicular to these. If any shoal is found, it is carefully developed, and the position of all rocks and other dangers, accurately determined. The boat's crew are made to pull a regular stroke, and every minute or half minute the leadsman sounds. Every three or four soundings, the two observers take sextant angles of adjacent well-selected signals. The boat's positions are plotted on the sheet by the three-point problem, tracing paper, or a three-armed protractor being used. The latter is a graduated circle with the central arm fixed and the other two movable; and it expedites the work of plotting very much. The soundings are reduced to the plane of reference, and are spaced between the boat's positions. The character of the bottom, best anchorage, etc., is also indicated. Current observations are made, and a boat is sent outside to write up the sailing directions of the entrance. The chart is now finished. The experience of many years has led me to the conclusion that a good hydrographer is born with natural qualifications. Men of scientific ability, with fine mathematical educations, often make very poor hydrographers. Their lines of soundings are not run with judgment, their angles will not plot because of badly-selected signals, they did not understand the currents, or something else is wrong.

In surveying a large bay, a polyconic projection is used. This is easily constructed for any latitude from the printed tables. With a theodolite or transit and a plane table, extreme accuracy can be attained. Many readings of each angle are taken continuously, and the instrument reversed. The triangles must be made to close within three or four seconds, and the sides are calculated for plotting With the plane table, the topography is run in without difficulty. The telemeter is now extensively used in determining distances.

In making a reconnoissance, or running survey of a coast, it is necessary to have several good chronometers, with their errors and rates carefully determined, and a full set of astronomical instruments. A complete deviation table for the steering compass is made out, as it is depended upon for the directions of the constantly changing base line. As the vessel proceeds, frequent azimuths are taken as checks. The vessel starting from a known position steers a careful course, with a constant speed. Natural objects on shore are cut in by the sextant, or by theodolite, if the vessel is steady, and the distance of the shore line constantly determined. A continuous sketch is made of the appearance of the coast. A steam launch or launches are sounding nearer the beach, and their positions are determined frequently, especially upon each change of course. The observer in the launch can determine his distance by taking the mast head angle ; and at the same instant, upon the displaying of a preconcerted signal, such as hauling down a flag, a person on the vessel takes the bearing of the launch, or an angle from her to some shore object. Both ship and launch take frequent soundings at regular intervals. Upon the approach of darkness, the vessel anchors or stands off and on, and resumes work at the same place in the morning. Every few miles, if possible, a party is landed to take astronomical observations for position, and astronomical bearings of prominent objects in both directions. If the launch discovers a harbor, a survey of it is made, as also of any reefs or off-lying dangers. To determine the contour lines of the bottom near the coast, the vessel on returning can run zigzag lines between 100 fathoms and shoal water. The chronometers are carefully re-rated at the first known position, and forward and backward interpolations made, if there has been any change. The projections are always polyconic. Such a survey as the above is

only made where there is a necessity of some knowledge for purposes of navigation. Charts, when published, are, of course, on the Mercator projection.

Naval vessels have done a great deal of work in looking for and establishing or removing from the charts, reported dangers. Very frequently merchant vessels report islands, rocks or breakers not on existing charts. A man-of-war is then sent, at the first opportunity, to examine the locality. In the North Pacific alone, there are more than 3,000 reported dangers. Frequently the same island has a half dozen positions assigned it, differing perhaps fifty miles. There is a great work to be done in the surveys of the Pacific Oceans, and the maritime nations of the world should each do their share.

Captain Joseph Skerrett, in command of the United States Ship "*Portsmouth*," removed many of these reported dangers from the charts, and surveyed others, found to exist, between 1872 and 1875.

Of recent years, naval officers, under orders from the Bureau of Navigation, have made telegraphic determinations of important points over a large part of the surface of the globe. These determinations have been made on the coasts of Spain and Portugal, the Canaries, Cape de Verdes, Uruguay, Brazil, the North and West Coasts of South America, Central America, Mexico, the West India islands, Siberia, Japan, China, the Phillippines, and joining the English system at Singapore.

The necessity of this work may be understood, when it was found that an observatory in Europe was out two miles in longitude. The accuracy of this method is simply due to the fact, that the unknown position is connected with a known position by telegraph, and the observers are thus enabled to keep a constant comparison of their chronometers. When the observers mark the stars' passage, over the wires of the instruments, upon both chronographs, nearly all the possible errors are removed.

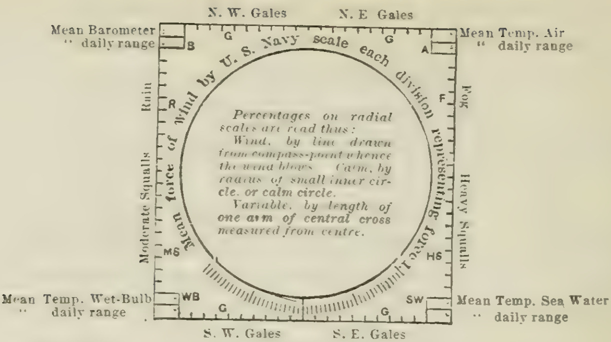
About two years since the United States Hydrographic Office established branch offices in Boston, New York, Philadelphia, Baltimore, New Orleans and San Francisco, in order to cultivate closer relations with the shipping of those ports. The Hydrographic Office had in its possession much information, valuable to the merchant marine, but there were no means of dispensing it. That office, also, desired the assistance and coöperation of merchant captains, in gathering meteorological and other data, which could be utilized

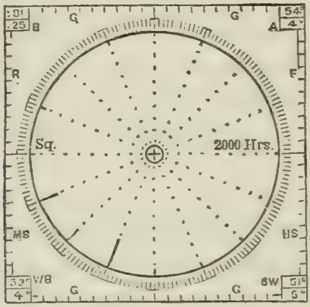
for the benefit of the mariner. Two naval officers are stationed at each branch office, and are furnished with charts and sailing directions for all parts of the world, which are kept corrected to date. They have also, for reference, a library of all kinds of nautical works. An excellent chronometer, with its error determined daily, is placed where it is accessible to the public, and a fine standard barometer and thermometer are kept for comparisons. A time-ball is dropped daily, at noon, on a staff erected where it can be seen by the shipping in port, thus enabling captains to get the error and rate of their chronometers. Every vessel is boarded upon arrival, and all the data possible is obtained from the officers and log book concerning storms, trade winds, currents, fogs, ice, water-spouts, wrecks, buoys adrift, meteors or unusual phenomena of any kind. In return, the captain is given a pilot chart and the error of his barometer, and is invited to bring his barometer and charts to the office for adjustment and correction. A captain about to leave port comes to the branch office, and obtains information about the best sailing route for his voyage, charts needed, probable winds and currents, dangers to be encountered, and knowledge of the ports he proposes to visit. Notes for the entire voyage are frequently given, and the advice is not theoretical, for it is based upon a vast amount of actual data gathered from the experience of practical men. The captain is also given the latest pilot chart, notices to mariners affecting his voyage, light lists, buoy books, and, during the cyclone period, a pamphlet upon the way to avoid circular storms. Many other monographs, upon such subjects as the magnetism of iron ships, uncertainty of fog signals, etc., have also been distributed gratuitously. A light list for the United States, contains all the lights, with full description of their character, visibility, location, height and kind of tower and buildings, etc., arranged in geographical order from Maine to Texas, and on the Pacific Coast. The buoy books, in the same manner, give full descriptions of day marks, with sailing directions for entering the ports. An American captain going on a foreign voyage, is also given the light lists of the countries he expects to visit. No other country treats the mariner as liberally in this respect as ours, and it is very gratifying to hear daily the compliments paid Uncle Sam for the interest thus manifested.

The following is some of the work of the six branch Hydro-

graphic Offices during the year 1885, with sufficient evidence to lead to the belief that it will be largely increased in the future: 11,750 vessels were boarded, and 5,343 barometers were adjusted; 16,836 notices to mariners, 1,329 light lists, 4,269 buoy books, and 15,733 pilot charts were given away, principally to masters of vessels. These offices also collected 622 reports of ice at sea, 233 fogs, 175 storms, 2,236 limits of trade winds, 1,120 wrecks, and very much other miscellaneous data, which was all utilized in the construction of the monthly pilot chart. Information was given at the offices to 10,870 people. One year ago the collection of information regarding the use of oil in storms was begun and was published each month on the pilot chart. Very general interest was aroused among sea-faring people, and now few vessels go to sea without some heavy vegetable or fish oil for this purpose. The testimony is conclusive that it is of very great benefit, and its use has no doubt saved many vessels from foundering or very serious damage.

When a vessel is starting upon a long voyage, the captain is requested to keep the hydrographic meteorological journals. If he accedes, he is furnished with all the necessary general sailing charts, and upon the conclusion of his voyage, gets a full set of meteorological charts. During 1885, 620 of these journals were placed upon vessels of all nationalities. The object is, to accumulate sufficient data, in connection with the logs of our national vessels, to construct reliable meteorological charts of all seas. A series of twelve monthly meteorological charts for the North Atlantic have been issued, and sufficient data is now in hand to complete those of the South Atlantic. The North Atlantic charts were constructed from the data of over 2,000,000 hours of observations, extending through a period of forty years. These charts, show graphically, in a form readily understood, all the phenomena in which the navigator is interested. Instead of hunting through hundreds of pages of printed matter, the master of a vessel can see at once how to lay his course, in order to secure favorable winds, and the character of weather he may expect. The ocean is divided into five degree squares, and the data are represented as seen in the following form:





This form shows the true direction and mean force of the wind during the month, calms, variables, rain, fog, gales, moderate and heavy squalls, mean of the barometer, temperature of the air, wet bulb, and sea water at surface, with their mean daily ranges.

The Pilot Chart of the North Atlantic is published on the 1st of each month, and embodies all the information received during the preceding one. In the upper left hand corner is printed, all the notices to mariners, the new charts issued since the last one was published, and some of the more important reports of the use of oil. In the lower left hand corner is a storm card, showing exactly what to do under all circumstances when overtaken by a cyclone. In the lower right hand corner is a summary of the weather of the past month, and what is to be expected during the present one. The positions, with the date when they were seen, is given of all sunken and floating wrecks, buoys adrift, waterspouts, whales, and icebergs. The floating wrecks are usually abandoned in the track of vessels, and are very dangerous to navigation. When once in the Gulf Stream, they are carried towards

the coast of Ireland, and are dreaded obstacles in the path of all trans-Atlantic commerce. As they are generally only just awash, and cannot be distinguished in a fog or at night, a knowledge of their location is very essential to shipmasters. By following the reported positions of floating wrecks and buoys, a very great amount of information is obtained, of the direction and velocity of the ocean currents. As an illustration, the case of the lumber-laden schooner "*Twenty-one Friends*" may be taken. Abandoned March 24, 1885, near the Capes of Virginia, she drifted nearly in the axis of the Gulf Stream until September 13th. On September 29th, she was within 300 miles of the coast of Ireland, and on December 2, 1885, was 100 miles from Cape Finisterre, Spain. On the January pilot chart, the positions of twenty-seven different wrecks are shown, and each of them may be considered as dangerous to navigation as a rock or reef. The limits of the ice field is exceedingly important to the trans-Atlantic steamers during the spring and summer months. A safe route is laid down each month between New York and the English Channel, and the managers of steamship lines carrying passengers now require their vessels to follow it. When several steamers collided with icebergs last summer, the press of the country pointed to the fact that they had recklessly abandoned the safe route laid down on the pilot chart. I have no hesitancy in saying that I believe that much property and many lives have been saved by the knowledge of the use of oil, and the positions of icebergs and wrecks conveyed by the monthly North Atlantic Pilot Chart. In each five degree square is shown, by arrows and cross-bars, the direction and strength of prevailing winds. The limits of the trades, and the best sailing routes to and from the equator, to New York and the English Channel, are also laid down. This last information is very valuable to masters of sailing vessels, and no doubt results in materially reducing the length of passages.

Judging from the testimony of able critics, the present organization of the United States Hydrographic Office is most excellent; and it only needs liberal appropriations by Congress, to greatly extend its usefulness, and place it ahead of any similar office in the world.

THE CULTIVATION OF FLAX IN THE UNITED STATES.

By JOHN SHINN,

Member of the INSTITUTE.

[*Read at the Stated Meeting of the* INSTITUTE, *Wednesday, March 17, 1886.*]

COL. CHARLES H. BANES, in the Chair.

MR. SHINN spoke as follows:

FLAX AND LINEN.

Among the numerous fibres that contribute to the clothing and household comforts of mankind, there is no single one of greater importance than flax, which, when made into woven fabric, is known as linen.

There certainly is no material capable of textile adoption which has so wide a range, since flax furnishes a fibre suited for the finest as well as the coarsest fabric, clothing for the wealthy as well as for the poor.

Flax flourishes in all climates and soils. Egypt, in the days of the Pharaohs, extensively cultivated flax for the manufacture of linen, where it formed the raiment of the wealthy and refined portion of society while living, and was employed as the only appropriate fabric for protecting their bodies from decay after death.

Of the true history of the ancients in the days of the Pharaohs, as manufacturers of textile fabrics, we know but little, and that only by what is disclosed by the mummy pits. Mummies have been found partly wrapped in old linen shirts, napkins and other articles of domestic use. These prove the general application of linen in Egypt to all purposes of ordinary life.

Professor John Greaves, in a book published by him in 1646, speaks of the "linen shroud" of a mummy which he opened, and says: "The ribbands or fillets by what I observed were of linen; of these ribbands which I have seen some were as strong and perfect as if they had been made but yesterday."

Egyptian priests wore linen only, as it was considered the purest fabric and especially adapted for sacred purposes.

We could afford to exchange some of the ancient records we now possess of great crimes and their consequent miseries for the knowledge of one lost art.

Even the pyramids bequeathed to us by Egypt in her glory, would be well exchanged for a few of her humble workshops and factories, as they stood in the days of the Pharaohs.

From the earliest dawn of history, flax has been successfully cultivated in the hot valley of the Nile; it also thrives as well in regions so cold as those of the North of Russia, in the sixty-fifth parallel of latitude. This is owing to its rapid growth. In Russia, it is an object of cultivation only in summer and in Egypt in winter, being sown in the latter country in December and January, just as the Nile has quitted the fields. It is harvested the following April or May. In Russia, it is sown in April or May and harvested in August and September.

Judiciously managed, where the labors of the farm are not suffered to encroach one upon another, there is no single crop, which requires so little skill and attention and affords so ample a remuneration for the outlay, as flax.

Instead of the farmer dealing with the plant as heretofore, by retting, breaking and scutching, the farmer should content himself with producing the straw and seed, leaving the subsequent processes of retting, breaking and scutching to those who have special establishments for that purpose, with the necessary improved fixtures and appliances, and whose capital and skill can be more economically and successfully employed.

We now manufacture cotton, wool, worsted and silk fabrics, and carpets of all kinds equal or better than the best imported. Having the capital, skilled labor and flax as good as the best from any part of the world, why should we not make our own linen?

Although it is a fact that many tons of flax are consumed in the United States in making cordage, carpet yarns, threads and coarse cloth, we make no fine linen, such as shirting, sheeting, toilet and table linen; here, then, is the opportunity for the employment of capital, producing a *staple* article with profits as large as those of cotton, wool and worsted fabrics in their most palmy days.

Is not this the question? As the South furnishes cotton to

run the cotton mills of England, should not the West furnish the flax to run the linen mills of Dundee and Belfast?

Ireland, in 1882, had 113,502 acres in flax, yet the imports of raw flax that year in the United Kingdom were over $20,000,000 in value.

In the year 1883, Ireland had only 95,943 acres in flax, producing 18,464 tons of scutched flax, and in the same year the imports of raw flax into the United Kingdom were 77,347 tons.

The State of Illinois alone that year, 1883, had 90,000 acres in flax, and most of the straw was burned for want of a market.

The fertility of our Western lands, improvements in machinery and the energy of a free people should enable us to compete with the poorly-paid labor of Europe.

On the subject of wages and agriculture in England, Consul Shaw, in a letter to the State Department, dated at Manchester, January 5, 1885, says as follows:

"From a careful study of the cost of preparing the ground and putting in and harvesting crops in this country, I am fully satisfied that farm expenses are more than 100 per cent. dearer in many cases here than they are in America, notwithstanding the much higher wages paid with us." (See Consul's Report, No. 50, February, 1885, page 316.)

I will now produce a few facts and figures to show the quantity of imported linens required to supply our home trade, also the extent and quantity of flax now grown in this country, and that the fibres of this flax straw *now wasted*, can, by improved processes and machinery, be manufactured into linen equal if not superior to that imported.

Consul Wood, of Belfast, Ireland, in his letter to the State Department, of January 8, 1885, speaks as follows: "With regard to the entire manufactures from flax, except yarns, in Ireland, the returns show that about seventy per cent. are exported to the United States, and of the same class of manufactures from the whole United Kingdom, about fifty per cent. go to the United States. The average value of the exports for the past five years is $13,883,685."

The imports of manufactured flax into the United States from 1871 to 1881 amounted to $177,747,371, or nearly $18,000,000 per annum.

The importation of linen, in 1883, was as follows:

Brown linen under 30 cents, yard, ...	$10,924,649
Brown linen above 30 cents, square yard, ...	2,280,120
Handkerchiefs under 30 cents, yard, ...	488,409
Handkerchiefs above 30 cents, square yard, ...	585,672
Burlaps, etc., ...	4,391,675
Thread, lace and insertings, ...	1,012,759
Thread and twine, ...	723,654
Other flax manufactures, N. O. P., ...	814,614
Total imports of flax manufactures, 1883, ...	$21,221,552

It must be considered that these figures are those of the importers, and not the value for which the goods sell in the United States. It is a well known fact that importers *do not over*-value the goods imported under an *ad valorem* tariff.

The flax spinning business of Europe comprises at present 3,000,274 spindles, distributed as follows:

Ireland, ...	874,788
France, ...	500,000
Austria-Hungary, ...	384,908
Germany, ...	318,467
Belgium, ...	306,040
Scotland, ...	265,263
England and Wales, ...	190,808
Russia, ...	160,000
Total of spindles on flax at present in Europe, . .	3,000,274

The whole number of power looms in use in the year 1884 in Europe on all class of goods, is reported as 87,129, of which Ireland had 23,677. There are no statistics to be had of hand loom weaving, though no small amount of it is still done. It is employed to some extent in the manufacture of handkerchiefs and the finer quality of linens.

Russia is reported as having only 160,000 spindles on flax and 3,000 power looms. That country, it is stated, had in 1883, 2,000-000 acres in flax, out of a total of 3,185,074 in Europe. More than half of the flax grown in Europe is raised in Russia. It was reported that Russia in 1883, raised 250,000 tons of flax, of which 54,310 tons was sent to the United Kingdom. In 1882, Russia sent 74,489 tons. Large quantities of flax are also spun and woven by hand in Russia. In case of an extended war with Russia,

England must look elsewhere for her supplies of raw flax or else stop her linen mills.

The area devoted to flax culture in the United States in 1883, was estimated to be 1,750,000 acres, with a yield of nine and one-half bushels per acre, a total of 17,525,000 bushels, valued at nearly $20,000,000. The fibre from the straw, allowing 350 pounds of fibre to the acre (small yield) would equal 612,500,000 pounds, which at only ten cents per pound, would be valued, for fibre only, at $61,250,000.

The area of flax culture in the United States for the year 1885, I have not been able to get, but it will not be less than that of 1883; it will probably be at least 2,000,000 acres, as the demand for flax-seed to make oil, is on the increase. Linseed is quoted, July, 1885, in Chicago, at $1.24 per bushel.

The great value of linseed in the United States, for extracting oil and for making oil-cake, and also because of the exceeding worth of the fibre of the flax plant, make the crop of that plant one of the most profitable that can be raised in the Northern, Western, or Middle States.

Owing to the cost of labor in this country, it will not pay to "pull flax;" it should be cut as low down as possible by a reaper and self-binder, or a gleaner and self-binder after a reaper, which will allow the straw to dry before bundling; the straw should be well cured in the field. If it is desired to get the fibre out "long line," the seed should be threshed out by a threshing machine, such as is used on rye straw, because such a thresher takes off the seed and keeps the straw straight. "Dew retting" and steeping the flax in earth pits should be avoided, as there is no control over the elements, and out-door retting is not reliable; many lots of good flax are spoiled by cold nights and by too much rain. In the process of retting out-of-doors, no rule as to time can be given. Flax has been fully retted in five days, yet similar flax has been thirty-two days in the same pit or pond, and was even then insufficiently retted.

In Belgium, flax is sufficiently cured in the field, so that it may be held over until the following summer, when it is steeped in slow-running water while the days and nights are warm. This enables the retting, or fermentation, when once started, to continue night and day until it is ready for "grassing," which is done before the rainy season sets in.

Flax from Belgium, when the above method is practised, produces a fibre which, for its excellence, stands pre-eminent, and commands the highest market price.

An English textile paper, comparing the flax of Belgium with the flax of Ireland, speaks as follows:

"The Belgium flax, so much admired and for which so high a price is paid, has been often *nearly* approached in color and quality by odd parcels of Irish flax.

"Courtrai flax is valued on account of its 'nature,' its fineness of fibre, its evenness, and its rich creamy color. Irish flax has been known to be of almost all lengths in one field; its color is almost as variable as the districts which produce it, while it is of fair fibre, and generally possesses plenty of 'nature.' * * * * * * If faith is to be placed in the statement that the color of the flax is owing largely to the method of steeping adopted, the variety of colors presented by Irish flax gives room for much meditation on the modes in vogue among Irish farmers, and on the necessity there is for a little more light on the subject. There is no reason to believe but that the true market value of Irish flax is obtained for it, and therefore it is all the more to be regretted that but eight shillings ($1.92) per stone (fourteen pounds) might be quoted as the average price of that fibre, while Courtrai flax can command an average of twenty shillings ($4.80) for the same quantity. It is of national importance that the quality and quantity of Irish flax should increase. In scientific and practical researches on the process of steeping lies the means of improving the quality, and this attained, an increase in quantity will follow as a matter of course."

From the above it is seen that the Irish flax brings less than fourteen cents per pound, the Belgian over twenty-seven cents, almost twice as much.

In 1883, Ireland had 95,943 acres in flax. The production of scutched or raw flax was 18,464 tons. To supply the linen mills of the United Kingdom, the imports of that year amounted to 77,347 tons of raw flax. (See Consul Wood's letter to State Department, January 8, 1885.)

If such are the wants of England, and such prices as the above can be obtained for Belgian flax, would it not pay in this country to raise flax for export? It will be said (as, indeed, it has been), that we cannot raise *good* flax in this country.

I will now give my experience on this point. I spent the last three months of 1882 at Belfast, Ireland. This entire time was devoted to collecting practical information on flax and its manufactures. Previous to this time, I had handled considerable flax, both in the straw and "scutched" state; flax that was grown in New York, New Jersey, Pennsylvania, Ohio, Indiana, Illinois and Oregon.

Some of the flax grown in New York State gave the unusally large yield of thirty-three per cent. of long line fibre from "dew retted" straw. Had this straw been properly "water retted" the fibre would have been equal both for quantity and quality to any that I saw or handled at the linen mills in Ireland, not even excepting some fancy lots from Belgium, which I was permitted to examine. I have handled flax grown in New Jersey and water retted, which, for color, lustre and strength was equal to the best Courtrai flax.

I have examined Oregon flax straw, which I found to be a superior article, giving a large yield of both seed and fibre. I have seen flax straw that was grown in Illinois, and for seed only. This straw was burned, as there was no market for the fibre, and yet this straw was as good and rich in fibre as any that I tested, which was grown in Ireland. If it had been properly water retted, it would have produced a first-class fibre.

If properly retted, all flax fibres are fine. This can be proven by any one who will take a strip of flax bark, in the green, unretted state, place it in the mouth, and, by chewing gently for a short time, the glutinous matter will be found well dissolved out (saliva being a good solvent, next to the gastric juices). The fibres will be found finely divided, perfectly white, and, while wet, easily parted by the thumbs and fingers, to any desired length.

This little experiment alone has often been the means of removing prejudice, and proving that fine linen can be made from what is called coarse flax, such as is grown for seed only, if only the straw is *properly water retted.*

The question now is, what is "retting?"

Flax straw, after the seed has been removed, *plainly* speaking, consists of three parts—sap, fibre and "boon." The only valuable part being the fibre, the sap must first be dissolved out, and this

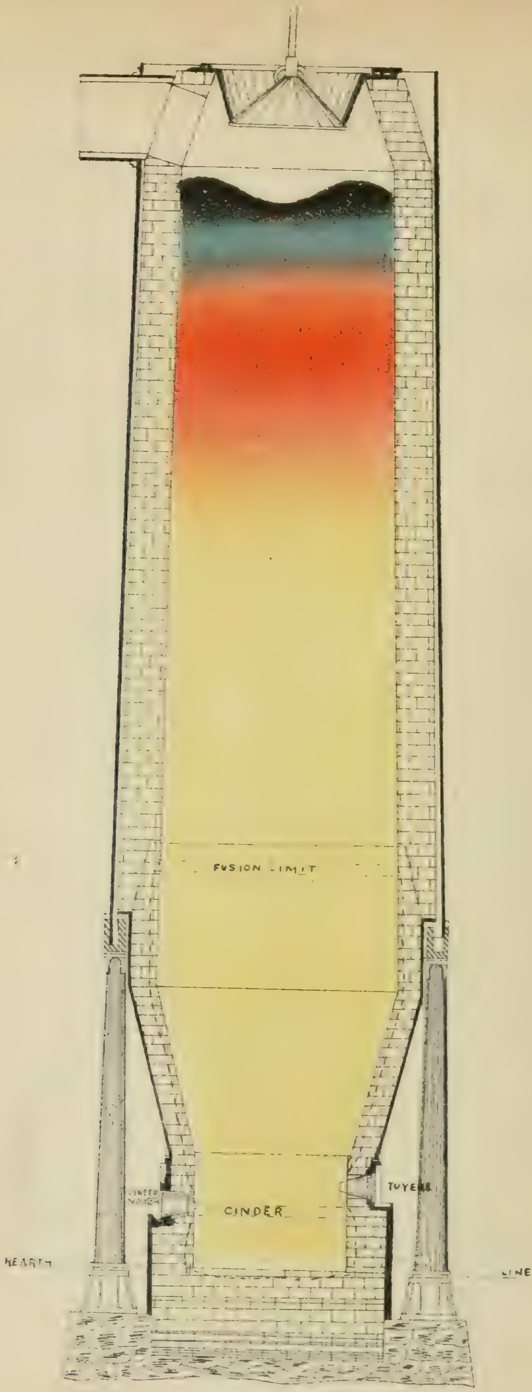


PLATE IV.

can only be done without injury to the fibre by fermentation, after which fermentation the straw must be washed and thoroughly dried, leaving the fibre and "boon," which is removed by breaking and scutching, leaving the fibre free from the boon or shives. To get rid of the sap without injury to the fibre, color, lustre, strength and nature, is the object of steeping and retting.

Several persons, at various times, have advanced the idea that this could be done, and flax "cottonized," by putting the straw through a number of processes of steeping and boiling in solutions of caustic soda, sulphuric acid, or other chemical reagents; but all have failed, owing to the fact that the use of chemicals, and even the boiling, destroys the strength, lustre, and what the Irish call "nature of the fibre." Such was the case with Claussen's, Schenck's, Knowles', and other processes.

The writer, while in Ireland, visited a town called Dunmore to see some flax that had been so treated. The place had been fitted up, at a large outlay, with iron tanks, pipes, baskets and machinery for scutching.

The processes having proved a failure, the place was idle and the machinery for sale. There was a large lot of straw on hand that had been operated upon, which did not look bad. I went to a linen mill close by and had a conversation with the superintendent. I wanted to know the trouble. To use his words, "The flax is dead; it has no 'nature'; it will not spin." There were several tons of flax straw at the place which had been so treated, and which was for sale at any price that might be offered. It was worthless, and would not sell for tow.

In order to preserve the natural oil in the fibres (which is called the "nature") the flax straw must be kept from all corrosive alkalies, acids and boiling water.

This may be done by having the steeping tanks in a *warm* building, heating the water by steam in a *separate* tank, keeping the room warm by steam pipes around the room. This will insure a uniform heat throughout the steeping tanks, and the process of retting will not be checked by cold nights or wet days, and the process may be carried on summer and winter. The retting will be under control, and there will be no over-retting, as is often the case with dew retting, when the flax cannot be taken from the fields while wet, and it often happens that the flax is not only

"retted," but *rotten*, the natural oils in the fibre and the lustre being destroyed

Flax straw that is uniformly water retted will scutch well, the fibres will be free from shives, and, if used for long line, will make less tow in heckling; will spin well. As most of the gum is dissolved out without loss of the "nature," the goods will bleach at less cost and have more gloss and strength than flax poorly retted.

If tangled straw, such as is grown in the West for seed, be used and run through the common grain thresher, the straw will be well and uniformly retted, the fibres of good color and strength, fine and glossy, with plenty of "nature."

The ultimate fibres of flax are short, not long, as some suppose. They are only from one to two inches long, being lapped or shingled upon each other in the progress of growth, forming long hair-like filaments, which latter many have mistaken for the ultimate fibres themselves.

Take the finest fibre of flax that is visible to the naked eye! Under a microscope each filament is a bundle of extremely fine short fibres, lapped upon each other as before stated. This can be easily demonstrated by any one who will take a thread from a *new* piece of linen, untwist the thread and moisten upon the tongue the thread or long filament. When exposed for a few minutes to the action of the saliva, the points of the short fibres may be seen starting from its whole length when gently drawn between the thumb and finger. It is a curious fact, though contrary to general belief, that these fibres are equally fine, so far as can be ascertained by the use of the microscope, whether from what appears to be fine or coarse flax. The difference between what appears to be fine and coarse flax, such as is grown for seed only, is this: in that which appears coarse, the filaments are more firmly cemented by the glutinous matter as to be separated only with some difficulty, but this may be overcome by proper water retting.

If the flax is well water retted, and free from gum, the filaments can be separated *mechanically* into short fibres, producing the long-sought "cottonized" flax; so that flax fibres may be spun into smooth fine yarn without passing the filaments through hot water.

With the spinning wheel in hand-spinning hot water is *not* used, and to show that fine spinning has been done by hand, the following is published as an account of an extraordinary feat in hand flax

spinning: "Miss Ann Macquillan, of Comber, in the County of Down, Ireland, in about the year 1815, from a parcel of flax grown in the barony of Castlereagh, spun, on a common wheel, yarn running up to sixty-four hanks, or 220,400 yards to a pound. She prepared the flax after her own peculiar system, by dividing the fibres with a fine needle."

Undoubtedly this flax was well *water retted*, and free from gum, and this flax was spun without hot water.

Many other such instances could be given where fine yarns were spun by hand, and no hot water used. We have no knowledge that the Egyptians used hot water, yet we have the knowledge that they did spin fine, smooth and strong flax yarns.

I advocate keeping the fibres and spun yarns out of boiling, or hot water, until it is made up into cloth, and then if it can be bleached without hot water, the greater and more lasting will be the lustre and strength of the fabric.

When I was in Ireland, the manufacturers in Belfast said that we could not make fine linens in America. I inquired the reason. They replied that we "had no climate." I asked, if they had one? if so, I had not seen it.

The flax spinning mills of Ireland are kept warm by steam. I was in one in December, 1882, an unusually cold day. As soon as I entered the spinning room I made the remark, "How hot!" and I noticed that the windows were opened at the top. I inquired the temperature of the room, and the superintendent, who was with me, informed me that the Government restricted the temperature to 80°, but he did not say what the temperature of the room was. I noticed that the water in the tanks of the spinning frames was quite hot, and some of them actually boiling, being heated by steam.

From this one can see that in Ireland, to enable them to spin flax the year around, they must make a climate by the aid of steam. We can do the same.

That we have no good flax grown in this country, and that we have not the proper climate to make fine linens, is nonsense.

Professor Waterhouse, of the Washington University, St. Louis, on that subject, says:

"Americans ought to surpass the rest of the world in the culture and manufacture of flax. With our wide range of latitude, the

conditions of soil, temperature and moisture best suited to the growth of this plant can easily be found. But this country ought not to be contented to raise flax merely for the sake of the seed; the largest profits are derived from the manufacture of exquisite fabrics. Consequently the attention of our farmers should be directed to the production of long line fine fibre. Our countrymen, often victorious over foreign art, need not hesitate to enter the list of competition. Surely, American ingenuity is not inferior to Irish skill. Our own mills will yet equal the woven miracles of European looms, enrich the nation with vast values, with which the creative power of skilled labor invests raw material, and retain in the United States the golden treasures which are now exported for foreign fabrics."

The late Peter Cooper, in a letter on home industry, says: "Economists justly ascribe England's wealth to its mills, indicating the time when those of Dundee and Manchester may be transferred to the valley of the Mississippi; we becoming the manufacturers and merchants of the world.

"Why wait for England's extremity, before sublimely illustrating the axiom that

Westward the course of empire takes its way."

Our country at present is just emerging from a great industrial and economical revolution; all classes of manufacturing industry were languishing, especially those of cotton and iron; yet never in the history of the country was capital so plenty and cheap. The New York City banks alone lately reported a surplus above the legal reserve of over $70,000,000.

There is no reason why we should not employ some of this surplus capital and establish a home industry in the manufacture of linens, worth at least $50,000,000 annually, giving employment to thousands, bringing the farmer and manufacturer close together, and the nearer the better? Agriculture gives to manufacturers food and raw materials; manufacturers furnish to agriculture clothing, tools and a *home market;* domestic manufacture animates and vivifies the production and interchange of commodities; without one, the other languishes and dies.

"The nation which begins by exporting only raw products of the soil, must in the end export or starve its population." They will find that their markets are too far off, and going further and

further, they will find they have lost most of the value of their crops in the cost of transportation. This is why good flax is burnt in the West, and corn is used there for fuel.

With these facts and circumstances before them, it might be well for capitalists to direct their attention to the subject, in order that they may reap the manifest advantages which may be derived from the cultivation of flax and its manufacture into linens for a home and a foreign market.

The LAW of CYLINDER CONDENSATION in STEAM ENGINES.

By L. d'Auria.

The weight of steam condensed at each stroke of piston in the cylinder of a steam engine is intimately connected with the loss of heat sustained by the cylinder and piston masses during the period of the exhaust, and this loss is dependent upon the rate with which the cooling takes place.

Newton was the first to propose a formula for determining the rate of cooling in bodies, but Dulong and Petit, by means of accurate experiments, proved the inapplicability of Newton's formula, and taking into consideration the mass and nature of the body subjected to cooling, the extension and form of its surface, its radiating power, the temperature of the ambient, the excess of the temperature of the body on the temperature of the ambient, the nature and the pressure of the latter, they proposed the following expression for the rate of cooling, which is found very well accordant with facts, viz.:

$$u = ha^{t}\left(a^{e} - 1\right) + kp^{x}e^{y}; \qquad (1)$$

in which t, and p, are respectively the temperature and pressure of the gas with which the cooling body is in contact; e is the excess of temperature of the body on the temperature of the gas; and the remaining quantities are numbers to be determined by experience.

The first term of equation (1) on the right hand side is due exclusively to radiation; and as with reference to steam engines, the radiation of the internal surface of the cylinder is not dispersive, we can drop such term altogether, and in our case write simply

$$u = k\,p^{x}e^{y}. \qquad (2)$$

Dulong and Petit found y to remain constant for all gases and equal to 1·223; while x was found to vary from one gas to another.

For atmospheric air,	. . . .	$x = 0·450$;
" carbonic acid.	. . . .	$x = 0·517$;
" hydrogen,	. . . .	$x = 0·380$.

The value of c which enters the expression (2) is given by the excess of the temperature T of initial steam on the temperature t of the exhaust, or $c = T - t$; for, the loss of heat which occurs during a single stroke is a very small fraction of the total heat contained in the mass of the cylinder, and the mean temperature of the latter at the end of stroke cannot therefore be much less than the temperature T. As to the value of p, we have to substitute for it the mean pressure of the exhaust steam.

Now the weight w of steam condensed at each stroke is proportional to the rate of cooling u (equation 2); to the mean surface Q exposed to cooling during the stroke; and to the duration of the latter $\frac{1}{N}$, N being the number of single strokes performed per minute. Hence, we can write

$$w = \frac{K\,Q}{N}\,p^{x}\,(T - t)^{1·223}.$$

Denote by A, area of pistons; by S, the stroke; by n, the grade of expansion, and by P, the pressure of initial steam above zero. Then the weight of steam indicated up to point of cut-off (clearance included) will be proportional to

$$P\,A\,S\left(\frac{1}{n} + c\right) = \frac{P\,A\,S}{n}(1 + nc);$$

c representing clearance in fraction of stroke.

If we indicate by θ the amount of cylinder condensation expressed in fraction of the weight of steam indicated up to point of cut-off, we can put

$$\theta = \frac{K\,Q\,n}{P\,A\,S\,N(1 + n\,c)}\,p^{x}\,(T - t)^{1·223}.$$

Represent by f the surface of steam passages at each end of the cylinder in fraction of it; and by D, the diameter of the cylinder will be

$$Q = \left(2 + f + \frac{2\,S}{D}\right);$$

and consequently

$$\theta = \frac{n\,k}{P\,S\,N\,(1 + n\,c)}\left(2 + f + \frac{2\,S}{D}\right)\,p^{x}\,(T - t)^{1\cdot223}. \tag{3}$$

This formula applies equally to simple and compound ordinary engines; but when a duplex direct-acting pumping engine is concerned we have to take into consideration the pause which takes place at the end of each stroke, which pause is nearly equal to the duration of the stroke itself. In such case equation (3) is transformed in

$$\theta_1 = \frac{n\,k}{P\,S\,N\,(1 + n\,c)}\left(2 + f + \frac{S}{D}\right)\,p^{x}\,(T - t)^{1\cdot223}. \tag{4}$$

Expressing temperatures in degrees Fahrenheit, and linear measures in feet, the writer has determined the values of k and x from few cases in his possession as following:

$$k = 0\cdot64 \quad ; \quad x = 0\cdot296.$$

[These values must not be considered as definitive ones, and it is to be hoped that engineers who are in possession of reliable data will not hesitate in applying them for a better determination of k and x, and make known their results.]

The above formulas can be made more handy by expressing T and t in friction of P and p. In such case we have for ordinary rotative engines

$$\theta = \frac{417\cdot15\,n}{P\,N\,S\,(1 + n\,c)}\left(2 + f + \frac{2\,S}{D}\right)p^{0\cdot296}\left(\sqrt[6]{P} - \sqrt[6]{p}\right)^{1\cdot223}; \tag{5}$$

and for duplex direct-acting pumping engines

$$\theta_1 = \frac{417\cdot15\,n}{P\,N\,S\,(1 + n\,c)}\left(2 + f + \frac{S}{D}\right)p^{0\cdot296}\left(\sqrt[6]{P} - \sqrt[6]{p}\right)^{1\cdot223}. \tag{6}$$

In compound direct-acting pumping engines without cut-off valves,

$$p = P\left\{\frac{r\,(1 + c) + R}{r\,(r - 1)\,(1 + c)}\ \text{hyp log}\ \frac{r\,(1 + c) + R}{1 + c + R}\right\} = P\psi;$$

R being the receiver space in fraction of the volume displaced by the high pressure piston at each stroke, and r the ratio of the cylinders. Hence for the latter case we have

$$\theta_2 = \frac{P\,N\,S\,(1 + c)}{417\cdot15}\left(2 + f + \frac{S}{D}\right)P^{0\cdot296} \times P^{\frac{1\cdot296}{6}}\,\psi^{0\cdot296}\left(1 - \sqrt[6]{\psi}\right)^{1\cdot223};$$

or

$$\theta_2 = \frac{417\cdot15}{P N S (1 - c)} \left(2 + f + \frac{S}{D}\right) \varphi^{0\cdot296} \times P^{0\cdot500} \left(1 - \frac{6}{1} \varphi\right)^{1\cdot223};$$

or

$$\theta_2 = \frac{417\cdot15}{N S (1 - c) \sqrt{P}} \left(2 + f + \frac{S}{D}\right) \varphi^{0\cdot296} \left(1 - \frac{6}{1} \varphi\right)^{1\cdot223}; \quad (7)$$

in which

$$\varphi = \frac{r(1 + c) + R}{r(r - 1)(1 + c)} \text{ hyp log } \frac{r(1 + c) + R}{1 + c + R}.$$

Examining formulas (5) and (6) it can be seen that, other things remaining the same, cylinder condensation would increase almost directly with the grade of expansion. But observing that whenever the grade of expansion n in a steam engine is increased a greater initial pressure P, is also required in order to obtain the same horse-power; it follows that the value of θ, in practice does not appear to be so much influenced by the point of cut-off as it has been stated above.

The most effective way to reduce cylinder condensation is by increasing the piston speed, which is clearly shown by the foregoing formulas.

A New Induction in Spectroscopy.—There are reasons to suspect that the spectroscope has not told us the entire truth of gaseous nebulæ, and that solid bodies, varying greatly as to number and size, are frequently important constituents of them. Probably nebulæ vary indefinitely in the relative proportions of the solid and gaseous matter in their composition, from those which are nearly purely gaseous to those which contain scarcely anything but solid bodies. If these were exceedingly numerous, so as to overpower the gaseous spectrum of the nebula by the continuous spectrum they gave, and yet none were sufficiently large to appear as a distinct star, we should have presented to us the very features we recognize in the Andromeda nebula, and Sir John Herschel's provision, made more than half a century ago, would be realized, that "the great nebula in Andromeda may be, and not improbably is, optically nebulous owing to the *smallness* of its constituent stars. The cause of the appearance of these temporary stars still remains to be found. If we accept Denning's observations as proving that meteor-streams moving with a velocity of 200 miles a second and upwards are features of interstellar space, the passage of such a stream through a nebula might produce all the phenomena of a temporary star.—*Observatory, October, 1885.*

HISTORY OF THE ELECTRICAL ART IN THE UNITED STATES PATENT OFFICE.

By C. J. Kintner.

[*A Lecture delivered before the* Franklin Institute, *January 25, 1886.*]

I once heard a member of Congress say to some of his constituents who were doing Washington City, from the tourists' standpoint: "Go first to the Smithsonian Institute where you will see all that God ever made; go thence to the Patent Office where you will see all that man ever made."

This advice, although given in jest, contained, at least so far as the Patent Office is concerned, much more truth than the speaker imagined.

The American patent system virtually dates its origin from the Constitution, in the eighth section of the first article of which our forefathers inculcated these words:

"Congress shall have the power to promote the progress of science and the useful arts by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."

Out of this grew legislation concerning patents as early as 1790, when the first revised statutes became law.

No organized system of granting patents was developed until 1836, when the Patent Office sprang into existence, and the law was amended so as to develop substantially the system in vogue to-day. From that time to the present, just a half a century ago, there have been no material changes in the revised statutes, and there has resulted from this wise legislation the most wonderful advance in the arts and industries the civilized world ever knew.

I am invited to address you to-night, upon the historical electrical apparatus of the United States Patent Office.

You will pardon me if I broaden the scope of my remarks to such an extent as to include or make them commensurate with the growth of the electrical art as developed in and by our patent system.

In the Patent Office we recognize and protect by patent all inventions and discoveries coming under any one of the following

classifications: (1) an art; (2) a machine; (3) an article of manufacture; and (4) any improvement upon any one of the foregoing.

The limited time at my disposal will not permit me to give definitions of these statutory classifications, so I will simply indicate to you that the Patent Office recognizes about twenty-four classifications in the arts beginning with the oldest art known to man, Agriculture, following with the arts of Textiles, Metal Working, etc , and ending with the youngest and to us the most interesting—Electricity. Each of these arts is divided into classes and each class into sub-classes for the convenience of search and for the the sake of an orderly arrangement of the records in the Office.

One principal examiner has charge of each art and is supplied with from four to eight assistants, dependent upon the demands of his art.

The electrical branch of the Office prior to 1881, embraced one sub-class known as Class 36, Electricity, under the Division of Philosophical Instruments. In that year the rapid growth in the matter of electrical inventions made it necessary to make a new classification, and philosophical instruments were taken by another examiner, electricity constituting an entire class, which has since become the most important art in the Patent Office.

The introduction of the telephone, based upon Alexander Graham Bell's patent, No. 174,365, March 7, 1876, gave a new and wonderful impetus to inventions in electrical appliances. There had been, prior to that time, marked progress in telegraphs, and much ingenuity had been displayed by inventors in simplifying the methods of telegraphic communication by developing apparatus adapted for use between inexperienced operators by automatic, stylographic and printing telegraphs, but when this new and wonderful invention sprang into existence it seemed to instil new life into the inventive genius of the world. Prior to 1876, less than 2,000 patents had been granted on electrical appliances of all kinds.

So rapid has been the development that each year necessitates new classification, and a thorough reorganization of the entire classification was effected during the past year, creating in place of one class, nine, as follows:

Class 171, Generation.—Embracing all kinds of apparatus for the generation of electricity.

Class 172, Motive-Power.—Including electric motors, transmission of power, etc.

Class 173, Conductors.—Including all means of conveying electricity from point to point, and all apparatus for in any way facilitating the transmission of current without interruption.

Class 174, Medical and Surgical.—Including all applications of electricity for sanitary purposes.

Class 175, Special Applications.—Having reference to all miscellaneous applications of electricity, such as are found useful in other arts, as dyeing, tanning, machinery, etc.

Class 176, Electric Lighting.—Having reference to all uses of electricity for illuminating purposes.

Class 177, Signaling.—Including all devices used for transmitting indications or alarms and signals for specified wants or needs as burglar alarms, annunciators, railroad signals, etc.

Class 178, Telegraphs.—Including all methods and apparatus for transmitting information by codes.

Class 179, Telephony.—Embracing all appliances utilized in the transmission of articulate speech whether by electricity or mechanical telephones.

Each of these classes is again divided into sub-classes as the necessities of the case may warrant, so that under the existing classification there are found about 100 sub-classes.

Take as an example the class of telephony in which we recognize twelve sub-classes, as follows:

Telephones, calls.
" details, or attachments.
" electric,
" magneto,
" mechanical,
" radiophones,
" reed,
" relays and repeaters,
" systems, embracing central station apparatus.
" switches,
" switch-boards,
and anti-induction devices.

Each assistant examiner has charge of a definite number of subclasses of invention and he makes the examinations of all applications appertaining to the classes of invention under his immediate charge. The principal examiner has charge of the entire

art and supervises and passes upon all matters appertaining to the granting of patents in his particular art.

As at present organized, the force of the electrical division embraces one principal examiner, eight assistant examiners, three clerks and one stenographer. Some idea may be had of the amount of work done by this force by examining my late annual report to the Commissioner of Patents, from which I note that there were filed, during the year, 2,019 new applications; there were filed 3,679 amendments calling up old or rejected cases for further action. There were granted 1,320 patents, there were made 6,036 actions upon all kinds of cases, and there were abandoned by act of law 610 allowed cases.

With this very brief insight into the general method of doing business in the Patent Office, we are prepared to review the art from its earliest inception.

It is a remarkably strange fact that in this, the youngest of the industrial arts recognized in the Patent Office, very few of the earlier inventions which note great advances were ever patented in this country.

We find that many of the very best batteries known in the art were the result of laboratory experiments made by such physicists as Grove, Bunsen and Daniel, and were never made the subject of patents in America.

So, too, with the earlier friction generators; the broad principle of reactionary generators discovered by Hjorth, and the broad idea of the division of the arc light as developed by Messrs. Lacassagne and Thiers as early as 1856.

We note also that Starr King, of Cincinnati, O., took English patents for the broad idea of an incandescent lamp with continuous conductor in an exhausted globe, as early as 1845, but never patented in America.

It seems remarkably strange that this should be true, and I can only attribute as a reason that it is a generally acknowledged fact that men of science seldom patent their discoveries.

Many of the best inventions made known to the world have been donated by men of science to the public, and apparently for the reason that the scientist seems to be so deeply engrossed in his labor of love to which he devotes his whole soul, that he cares for little else than the gratification which his researches bring to him and his fellow-laborer.

It is particularly gratifying to us that this mysterious art comes within the domain of the scientist, and that such scholars as Faraday, and Ohm, and Ampère, and Varley, and Thomson, and Clerk Maxwell, and a host of others were and are its acknowledged patrons.

In treating a subject relating to the history of an art extending over a period of half a century, and embracing a matter of 10,000 patents, I can, of course, only touch here and there upon such matters to-night as note matters of interest or marked steps in the art, and I will note the progress chronologically, rather than by assuming to discuss any particular phase of the art extending through that period of time.

The records of the Patent Office show that the first patent disclosing any electrical appliance whatever was granted in 1833, July 22d, to D. Harrington, of Philadelphia, Pa., for an apparatus for curing diseases by electricity.

Strangely enough, we here find a native of the dear old city of Brotherly Love at the very threshold of an art displaying that commendable spirit of philanthropy for which her citizens have been noted since the days of Penn, and seeking by this new and wondrous art to extend the hand of brotherly love to a suffering companion.

However commendable the inspiration may have been which led Mr. Harrington to thus offer aid to his suffering fellow-men, I cannot vouch for the efficiency of his apparatus, which consisted in applying two metals of different electrical potential to the body in such manner as to generate an electrical current through the body.

I am of the opinion that no very gratifying results would be attained from its use unless it be assumed, as is often the case with this class of inventions, that the patient is to be blessed with a very large endowment of faith.

Mr. Harrington took out two more patents on apparatus of a similar nature in the following years 1834 and 1835.

These three patents are all that are found upon the records in the art prior to the establishment of the Patent Office proper in 1836. The original records of them were destroyed in the great Patent Office fire of 1836.

The first patent granted under the revised law of 1836, was to

Thomas Davenport, of Brandon, Vt., for an electro-motor on the 25th of February, 1837.

The motor is a curious relic, and although meagrely described, I will endeavor to give you a clear understanding of it, obtained from a study of the model and the specification.

The armature consisted of four axial magnets attached to a wooden wheel supported by a vertical shaft.

The winding of these magnets was continuous from one to the other, and the commutator brushes had their bearing on segmental strips, equal in number to the number of electro-magnets.

The field magnets, two in number, were arranged concentrically about the armature, and were composed of permanent magnets. It was not dissimilar in its action to the well-known Gramme machine.

On the 27th of June, 1838, the first derived circuit motor was patented to N. Walkly, of Tuscaloosa, Ala.

This motor, like that of Davenport's had an armature with axial magnets attached to a vertical shaft. The current was reversed through the armature at each half revolution by an eccentric and commutator springs analogous in their operation to the valve mechanism of a steam engine.

The field magnets were energized by a derived circuit flowing always in the same direction from the battery.

It possessed many remarkable features found in the best types of electric-motors of to-day, and probably failed in its efficiency only because of its clumsy commutator action.

Following closely upon the heels of the Walkly motor, came the Stimpson motor, patented on September 12, 1838. It is not dissimilar in its general appearance to the well-known Alliance magneto machine, and consists of an armature composed of a series of magnets arranged parallel to the revolving shaft which carries them, and so that both poles of these magnets shall be exposed to opposing field magnets located in planes parallel to their ends and radially fixed with relation to the revolving axis The commutators were arranged in a manner not unlike the well-known Gramme commutators, and the current was commuted through the armature magnets successively as they came into the effective field of the field magnets which were charged by an additional battery.

At this stage of the history of the art, there comes upon the scene of action the first inventor of lightning rods who seems to

have availed himself of the protection offered inventors by our patent system. Whatever may have been the merits of his invention, and whatever success he may have attained with his patent, there can be no question but that he, Joseph S. Barber, of Gloucester, Mass., deserves at least a passing mention in order that the rural communities of this great country may know to whom they are primarily indebted for the annual precipitation of lightning rod literature and persuasive eloquence in behalf of an assured protection from the ravages of one of Nature's most destructive elements.

This, the first patent upon lightning rods, was granted March 6, 1839, and to one versed in the peculiarities of statical electricity, the invention covered by it appears somewhat peculiar, and I may add, to be of doubtful utility. It consisted of a paraboloidal metal body, having its base attached to a wooden rod, the latter fixed at some elevated position above the structure to be protected.

Affixed to this paraboloidal body were several sharp points of metal projecting in all directions about it.

The inventor assumed that when a storm cloud approached, this metal shield would cause the bound electricity in the structure to be disseminated before the cloud reached a striking distance.

I do not know if the inventor ever located himself in a building so protected or, perhaps, I should say so exposed. Inasmuch as nothing is known of his future success, and the records show nothing more in his direct line of invention, I take it that it is entirely probable he did try it and with such a gratifying result to the public as might readily be expected, viz., total annihilation.

It is pretty generally assumed on the part of our countrymen that Prof. Morse was the first to patent the electric telegraph in this country.

This is a mistaken notion, as the records of the Patent Office show that Messrs. Wheatstone and Cook, of England, took a patent for their needle electro-magnetic telegraph on the tenth day of June, 1840, while Prof. Morse's patent followed only ten days later.

The Wheatstone and Cook needle apparatus consisted of several wires running to the distant or receiving station, in each of which was located a galvanometer adapted on closure of the circuit to cause a needle to vibrate to the right or left as desired.

It was necessarily cumbersome and never found a place among

the practical inventions of the art in this country. It stands upon the records only as one link in a chain of historical apparatus.

This patent also embraces some features upon underground conduits, which are of general interest at present in view of the attempts to force conductors under ground.

It was primarily to Morse's apparatus based upon his code of signaling and the use of a single line wire with his well-known recorder that we owe success in telegraphy. So well known is Prof. Morse's invention that it is not necessary to offer any description here, but simply to note that the original models on file in the Patent Office take the first rank among such historical curiosities as the Howe sewing machine, the Jacquard loom, etc., etc.

It is very curious to note also that the models made by Prof. Morse are marvels of workmanship and proportion when we consider the fact that he was pioneer in the art, and labored under difficulties known only to a great inventor struggling against fate.

In 1842, March 28th, the first patent was granted to Patrick Coad, of Philadelphia, Pa., for an improved galvanic battery for medical uses.

It appears as though the early history of the art looked entirely to your city for those men of genius who should devote their efforts in behalf of the afflicted. This invention notes only an improved manner of immersing the plates of a battery in a cell so as to indicate the quantity of current and also an improvement upon the electrodes used by the patient.

It is of no especial importance other than being the first galvanic battery protected by patent in America.

In 1846, April 11th, we find the first printing telegraph patent granted to Royal E. House.

It consisted of a key-board having keys controlling the rotation of a power impelled cylinder which in turn controlled the operation of a circuit breaker in the telegraph line, extending to a distant receiving station where was located a power impelled type wheel controlled by an electro-magnetic escapement.

This application, which was the parent of a large class of inventions known as printing telegraphs, was followed in 1848, December 5th, by Bain's automatic telegraph which was destined to avoid the Morse patent heretofore referred to It operated by or through the agency of an electrical current acting upon a circuit upon a paper

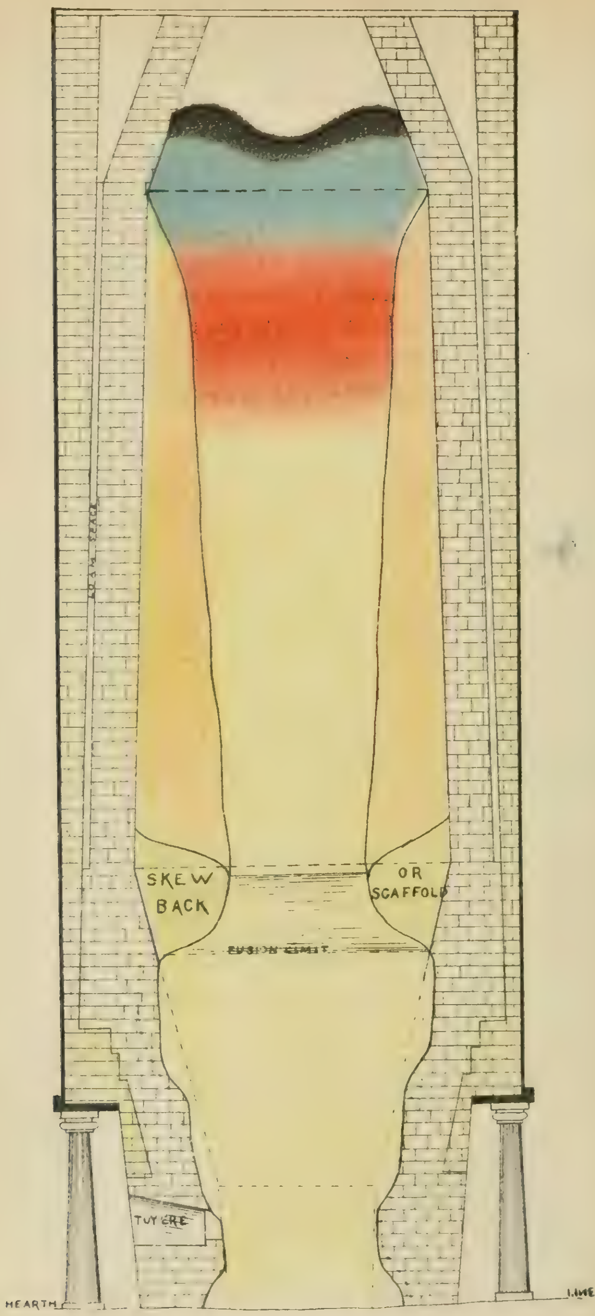

LOAM SPACE
SKEW
BACK
OR
SCAFFOLD
FUSION LIMIT
TUYERE
HEARTH
LINE

PLATE V

made sensitive by a chemical solution. Out of this patent grew the famous suit, O'Reilly *vs.* Morse, in which the Supreme Court of the United States held Morse's eighth claim, which was in effect to the use of electricity for the transmission of intelligence, to be void.

The first patent upon a straight current magneto-electric machine bears date of November 1, 1853, and was granted to Calvin Carpenter, of Pawtucket, Mass. It is substantially an Alliance machine with commutator arrangement for staightening or directing the current; the armature consists of a series of electro-magnets whose cores are exposed at both ends to the influence of permanent magnets arranged in front of them. The commutation of current is not substantially different from that in general use on this type of machines as now used.

I will now call your attention to the Page motor, patented by Prof. Chas. G. Page, on the 21st of January, 1854. In this motor the two armatures consist of long cores of iron which are adapted to slide with an oscillatory motion through two pairs of solenoids made up of successive sections which are brought into action by sliding commutators actuated by rods from eccentrics on the fly-wheel shaft, being entirely analogous to the cut-off mechanism used in a steam engine.

It was not, however, a practical motor, nor is any motor, so far as I can ascertain, which depends for its action upon shifting commutators actuated by eccentrics, for the reason that the element of friction is above the mean.

This motor is the more interesting to us because its inventor was an acknowledged authority in electrical matters in his day, was the associate of Prof. Henry, and the discoverer of what is known as the Page effect in the cores of electro-magnets. He was also one of the first examiners appointed in the United States Patent Office under the law of 1836.

On the 18th day of May, 1858, Messrs. Collier and Baker took out the first patent granted by the United States for an improvement in the arc light.

It consisted of two electrodes of carbon; the upper carbon was prevented from contact with the lower by a retaining diaphragm of metal through which its point projected.

It acted by a mercurial feed, the carbons being forced forward

by the mercury in which they were immersed. As a practical lamp, it was not a success.

By a strange coincidence during the same year the first patent upon an incandescent lamp was issued to Gardner and Blossom, composed of a platinum coil enclosed in a glass chamber, but this containing chamber was not exhausted.

This lamp was of course not practical. This year was also productive of the first successful duplex telegraph, invented by M. G. Farmer, and also what is known in the art as the Hicks telegraph repeater for transferring messages to successive lines.

In 1859, on the 20th of September, the well known Grenet battery was patented.

On the 26th of February, 1861, there was patented to Charles Kirchoff, of New York, an improvement in storage batteries which deserves special mention here. It stands out alone to-day as an invention at least twenty years in advance of its time, and the description and model are wonders of curiosity to those dealing with the question of storage batteries.

I venture to say that no one of the older patents in the art has been more generally quoted and appeared in the light of an annoying reference to those who imagined they were original inventors than the one under discussion

It is of the Planté type, composed of lead plates adapted to be charged as was Planté's battery. Kirchoff saw the necessity of increased surface for his electrodes and to this end proposed many forms consisting of corrugated plates, wire netting, perforated plates, etc. He well understood the necessities of the case and his specification discloses a knowledge of the art at once as wonderful as was his ingenuity in developing means of overcoming to him known difficulties.

He also developed an apparatus for charging each cell in succession while the charged cells were discharging upon an exterior working circuit.

I regret that I have not the model with me to show you the wonderful genius of an inventor who was developing an art destined to sleep nearly twenty years.

The next improvement in this line of invention was patented to C. G. Percival, of Brooklyn, N. Y., on November 9, 1866. It consisted of a wooden battery cell divided into two chambers by a

porous partition. In these chambers was placed powdered carbon or lead in such manner as to surround the electrodes.

This carbon or lead was saturated with dilute sulphuric acid, after which it was ready to receive the charge. This is the first storage battery having active material surrounding the electrodes.

On the 23d of April, 1867, a patent was issued to G. S. Leclanché for the famous battery now found with slight change in almost every telephone box in the land. It is too well known to need description here and stands as a land-mark in the list of useful inventions covered by patents.

I come now to an important invention by Prof. Page, covered by patent No. 76,654, April 14, 1868, and afterwards reissued on the 10th of October, 1871, by Prof. Page's assignees, the Western Union Telegraph Company, in such broad terms as to include all telegraphic apparatus wherein a main circuit is caused to operate or control a local circuit, and also the use of a retractile spring to an armature of an electro-magnet.

This is the famous Page patent, so long held by the Western Union Telegraph Company as a menace over the heads of other telegraphic corporations.

It consisted of the well-known form of induction apparatus with an automatic circuit breaker, and was invented by Prof. Page many years before he took a patent which was granted by virtue of a special act of Congress, he being an officer of the United States Patent Office, and therefore disqualified by law to take an interest in any United States patent except by inheritance or bequest.

This patent expired April 14, 1885, and thereby opened wide a great field, although it is extremely questionable if the reissue could have been sustained in its broadened aspect in view of modern Supreme Court decisions touching the question of broadened reissue patents.

We now note the appearance of the first double type wheel printing telegraph, patented to E. A. Calahan, April 21, 1868, and reissued to the Gold and Stock Telegraph Company, on the 25th of July, 1870.

This instrument was the first to utilize double type wheels, one of which printed letters and the other figures.

It has since passed into the hands of the Western Union Telegraph Company, and suit is now pending between said company

and local printing telegraph companies in New York City for infringement of its claims.

An interesting invention is found in a patent to two Frenchmen, Messrs. Chauvassaignes and Lambrigot, bearing date of July 28, 1868, wherein the message to be transmitted was marked in non-conducting ink upon a metallic tape designed to act as a transmitter by which the circuit of a telegraph line was broken and closed, and the message was recorded upon sensitized paper at the receiving station. Inasmuch as the rapid telegraph companies are using this invention as embodied in more improved apparatus to-day, this invention notes an early stage in an art then quite undeveloped.

I desire now to call your attention to an invention by one whose name appears for the first time upon the Patent Office records on the first of June, 1869. It is a patent for a vote recorder. This was Thomas A. Edison's maiden patent, and is a device for recording the ayes and noes of a voting assembly. Two circuit closers are located at each voter's desk, and connect from the battery with two indicators, one for the ayes and the other for the noes. In the same circuit is a metal cylinder covered with chemically prepared paper and adapted, when a circuit is closed at a voter's desk, to print either aye or no as desired. As the vote progresses, the cylinder is rotated and each voter's vote is silently recorded, the indicators at the same time checking the total vote. Since this patent was granted, Mr. Edison has taken over 150 patents, and I think I do not overestimate his abilities when I say that no other inventor has done so much to advance the entire art as has he.

Upon looking over his list of patents I find him accredited with no less than forty-five patents upon printing telegraphs alone, many of which are in daily use in our stock exchanges.

The gravity battery of Jean Armand Callaud, deserves a passing mention, and was patented October 17, 1871. It, like the Leclanché battery, is of such general public notoriety as to need no description here, and is perhaps in more general public use than all other kinds of batteries combined. It marks an important era in the art, in being one of the cheapest and most efficient of battery generators.

A passing mention must be noted here of the Gramme dynamo machine, patented October 17, 1871, which is the first ring arma-

ture generator patented in America. Its construction is too well known to need description at my hands. The patent has expired by limitation of a foreign patent, and the invention is now public property. The Wilde machine, so well known in the art as the first dynamo with field magnets excited from an extraneous circuit, was patented in the year 1866, November 13th, and is now public property also.

We come now to an interesting invention in the patent of J. B. Stearns, 126,847, May 14, 1872, for overcoming statical disturbances on long duplex lines by the use of condensers. Prior to this invention it was not possible to transmit accurately two or more messages on existing duplexes over distances exceeding from thirty to fifty miles. Mr. Stearns conceived the idea of giving to the artificial line of a duplex telegraph an artificial electro-static capacity which should equal that of the main or direct line. This he did by inserting adjustable condensers in a branch of the artificial line, and adjusting them until no false signals occurred. This was the first great step in successful long distance telegraphy. The patent has since been reissued by the Western Union Telegraph Company, Mr. Stearn's assignees, and suit has recently been brought under the reissue against the Baltimore and Ohio Telegraph Company, in New York. The patents are very valuable if they shall be sustained.

An invention, which is of special interest from an historical standpoint, is found in the patent to E. W. Siemens of April 14, 1874, which discloses the first unipolar magneto machine covered by patent in this country. It is so constructed that one pole of the field magnet lies within or is surrounded by the other pole, the armature being arranged to revolve or vibrate in the intervening field.

We now come to a dynamo which has peculiar interest at this time because it is the parent machine patented in America, which depends upon the now well-known reactionary principle found in many of the better forms of dynamos in use to-day. It was patented to Moses G. Farmer, April 13, 1875, and is not dissimilar in its general construction, to the series wound reactionary dynamos now found in public use. Although Mr. Farmer obtained a broad claim for the reactionary principle, it has since been discovered that Hjorth, Pacinotti, Siemens and others had patented and described, this applied principle in Europe as early as, and even earlier than

1870, so that this patent merely stands upon the record as being the first to claim an applied principle, which has since received such general and wide-spread application.

It is a remarkable fact that by a strange chain of coincidences many of the leading and essential features embodied in successful incandescent and arc lighting, and also in dynamo machines to-day are public property. It is only upon comparatively limited patents that existing light corporations are based, and this rightly by virtue of abandonment or public use on the part of the original inventors of these broad features.

The advent of the year 1876, the One Hundredth Anniversary of our National Independence, seems to stand out in bold relief as a year of progress in the electrical art.

Prior to the first of January of this year, the Patent Office records note, all told, 1,923 patents.

On the 7th of March, 1876, a patent was issued to Alexander Graham Bell for a speaking telephone, which gave a new impetus to invention and at once gave to the world an increased idea of the importance to be attached to that wonderful, intangible element—electricity.

From that date to the present, I cannot undertake to consider as I have in the foregoing remarks what individual inventions have been realized, and cannot even hope to give you a faint idea of what is disclosed in the 8,000 patents granted in less than ten years—more than four times the number previously granted in a period of nearly a half century.

In 1877, came Brush with his well-known dynamo and his improvements upon arc lamps, followed by Weston, Hefner-Alteneck, Thomson and Houston, and a host of others, until the list of inventors becomes almost legion.

You are all, I doubt not, quite as familiar with the existing state of the art disclosed by well-known apparatus in general public use, as am I, since the apparatus in such general use is but a copy of that disclosed by the Patent Office. Telephony has grown from the parent patent of Bell to include more than 500 patents; arc lights as many more, and incandescent lights and fixtures a like number.

Whole new classes of invention have grown up in the period of less than ten years, until as they multiply we are forced to ask when and where will this march of genius cease.

Capital has kept pace with this wondrous exposition of ingenuity and finds itself ever ready to exploit and put in public use the inventions spread upon our records until it has become almost an axiom that to patent an electrical device seems to assure the inventor at least some revenue for his pains.

Amid all this clamor for investment in this mysterious field, the patent sharp has not been idle, and I regret to say that many capitalists have met with sad reverses because of investments in worthless patents, or perhaps I should say, worthless inventions based upon patents.

It is a matter of deep regret that this is true, for a few such unlucky investments do vastly more damage than one can estimate, by frightening away available capital from commendable inventions. However this may be, I cannot express much sympathy for any man who will invest his capital without first ascertaining the probabilities of successful return.

One such a success as Prof. Bell's patent stands out as a Mecca of hope, towards which all avaricious eyes are turned and with a greed for gain which causes unfortunate investors to be swept into veritable maelstrom of distress. Such princely incomes as it has been Prof. Bell's and Mr. Brush's good fortune to attain, do not often fall to the lot of man, but rather tend to lure one on in the hope of some time reaching the goal of success.

I have sought in the preceding remarks to give you the written history as briefly as possible, of the electrical art as we find it outlined upon Patent Office records, taking here and there as landmarks some leading or interesting patent and tracing thus step by step its progress to the Centennial year believing you to possess, as do most of our newspaper reading communities, a general information of the general history of the art from 1876 forward. So much interest is now displayed in electrical matters, and so many are the facilities for attaining knowledge in that direction, that little need be said of the present history of the art, either in or out of the American Patent Office.

Every one who reads is familiar with the modern quadruplex by which four messages are sent simultaneously over a single wire —the invention of Messrs Nicholson and Edison.

The multiple synchronous telegraph of Delany was exhibited at your famous electrical exposition in 1884, as were indeed, thousands

of other interesting and important inventions which go to make up the more modern history of the art. These you saw, and learned by actual practical application of all the more important apparatus patented during the last decade.

I cannot close my remarks without saying something of the unwritten history of this wonderful art in the Patent Office, a history known only to the employés of the Office and oftentimes intensely interesting.

To you and to every one the published records of the Patent Office are open and he who runs may read.

No one but an examiner of the Patent Office, and particularly an examiner in the Electrical Division, can form any conception of the wonderful workings of the human mind. It is to him that the most wonderful (?) inventions are unburdened, and he is forced to wrestle with electrical problems which would almost cause Faraday and Ampère to turn in their graves! It is true that in the past, patents have been allowed to issue at which you have doubtless wondered, so inconsistent do they seem with existing laws, but the public can form no conception of the ignorance of alleged inventors in this art. So mysterious is the art to every one, that in the depths of that mystery reside visions of untold fortunes in alleged inventions which never had a conception other than in the murky brain of their mysterious authors.

Our chief difficulty lies in electro-medical appliances, and the alleged inventions in this direction are legion.

I remember a few years ago, an applicant filed an application for curing nervous affections. It consisted of a copper wire earthed at both ends and carried over the bed of the patient in a north and south direction; that was all. Of course, it was refused for lack of utility, whereupon the applicant produced the affidavits of at least a dozen neighbors to prove that his wife was benefited and restored to health by the use of this simple and alleged effective device. This availed him naught, a patent was refused, and he appealed his case to a higher tribunal, where he again lost.

Another instance I recall is the small neck battery adapted to be worn about the neck of the patient, being about two inches in diameter, and having no excitant. It was refused as being inoperative. The applicant, not to be daunted, was cunning enough to place upon the exterior surface a design, and to take a design

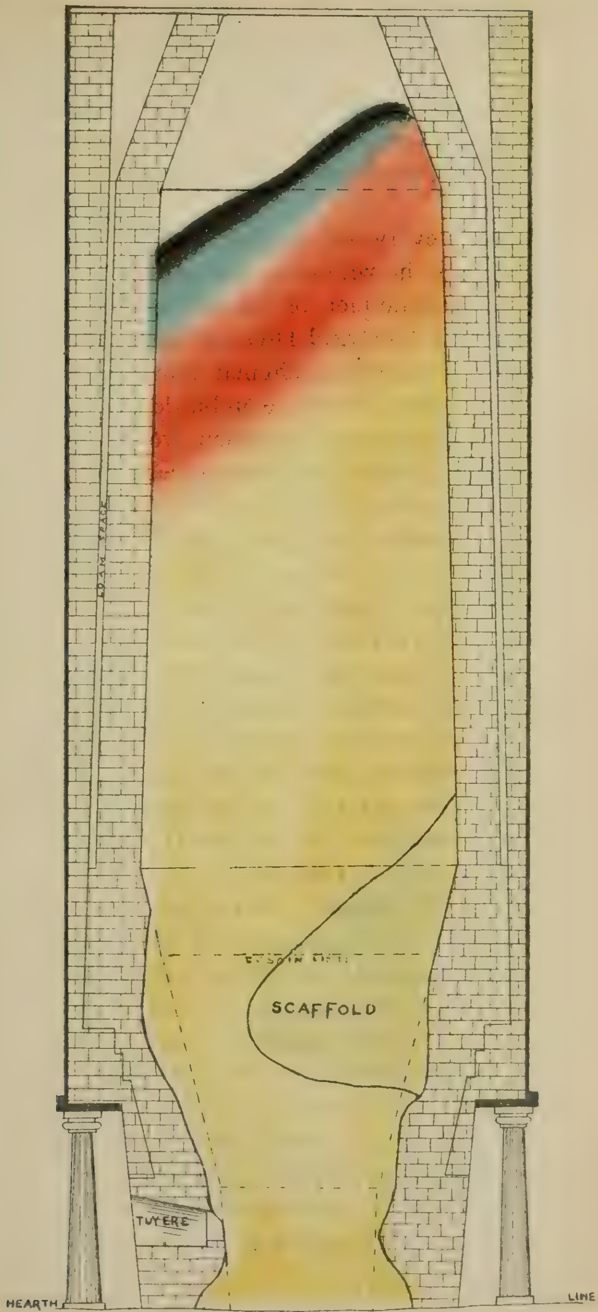


PLATE VI.

patent therefor, thus succeeding in accomplishing his end by getting the seal of the Patent Office. I have since seen a printed book of over 2,000 pages of testimonials from persons benefited by this alleged great electrical curative.

In another instance, an applicant devised an apparatus for generating steam in locomotive boilers, without the use of wood or coal. He first generated steam in the usual manner by the use of coal, and then caused this steam to actuate a local engine, and from it a dynamo, which generated electricity. This electricity actuated an electrical heater under the boiler, so that after once having started his locomotive, of course no more fuel was necessary. A clear case of perpetual motion. He was required to furnish a working model, which has not yet been received.

Perhaps the most amusing application which ever came under my observation, is that for an improved "Method of Obtaining Rain by Art." I will take the liberty of quoting from the papers, in order that you may form some idea of the peculiar idiosyncracies of this inventor.

He says:

"The object of my invention is to obtain rain by art as required, and where required on the earth, snow falling in colder regions, thus rendering the deserts fruitful, and in time D. V. opening up the Polar regions for settlement, and by withdrawing the rain from the atmosphere, relieving the tension from the ice in the Polar basins, thereby tending to preserve this planet, with all its inhabitants, from the destruction which is imminent, 2d of Peter, Chapter III, and Daniel IX–25, being in danger of fulfilment."

"I use a captive balloon, the cable being attended by a cable or wire to the earth. This cable or wire may be covered with lamp-black, if required, to cause it to absorb solar heat and partially melt ice spicula attaching themselves to it, thereby preventing its breakage.

"The electricity is conducted from the higher strata of the atmosphere in such a way as to produce intense heat and melt floating ice spicula in the air, and precipitate it as rain.

"In this way, the temperature of the higher atmosphere will be lowered, floating ice spicula will be disseminated and gradually the increase continued. Precipitation of ice at the poles of the earth

will not only be discontinued, but a counter action will be set up, bringing the ice from the poles to the equator, and dissipating it as rain in the desert and other arid regions."

His specification is at once a curious medley of scriptural prophesies and alleged scientific facts, the latter to be found only in the curious mind of the inventor; it is not more curious, however, than is an assignment filed by the inventor, which I quote in full as follows:

"Should I die, before the patent for obtaining rain by art is applied by me, I desire the government to work the patent, devoting half the profits to endow the widows' and orphans' homes, into which no clergymen will be allowed; the only prayers to be offered within the walls being those in Holy Scriptures; the only praise to God being the Psalms of David, and other songs of praise in the Holy Bible; the orphans to be instructed into Holy Scripture from infancy, such portions as are suited to their years. When beyond the age of twenty-one years (seventeen females), each to either translate from the Hebrew or Greek the whole Holy Bible, or write a copy of it with their own hand in their own language. The males not to marry until thirty-three years, the females until the age of twenty-five years. Should they become widows or widowers, and wish to marry again, they shall only marry widows or widowers of proportionate age; each orphan to be thoroughly instructed into that branch of science or art to which their mind shows a natural bent, scientific agriculture being prominently held forth to those who wish to adopt it; the girls to be fitted for the positions of governesses, teachers, etc., the widows to be taught branches of needle work, knitting, etc., so that the result of their labors may be devoted to the benefit of the inmates (and if possible to outside poor) in clothing, etc.; prayer and praise to be offered three times daily to the Almighty God. The use of flesh as food, if found practicable, under the observation of unprejudiced, scientifically educated physicians to be prohibited. Abundance of all edible vegetables, grain, etc., of which the leguminous will be in large proportion together with milk, butter, cheese, honey and fruits to be used. From the age of twenty-four to twenty-nine years, the males to contribute one-third part of the net profits of their labor towards the further endowment of their home. The right of amending this testimony for the benefit of all is reserved by me.

"I desire all the nations using the methods of my discovery, to similarly endow such widows' and orphans' homes.

"The other half of the profits to be given to my poor relatives, to be invested by them in profitable securities for their own use and benefit."

These are fair samples of many alleged inventions, which yearly come before the electrical examiner of the Patent Office, and as surely find themselves buried in the record of abandoned applications.

You will, of course, appreciate the fact that but little can be said of the secret history of invention, for the reason that the policy long pursued of preserving pending applications in secrecy must necessarily impress one with its entire fairness to all.

I have made no breach of my official relations in enumerating the cases above referred to, for the reason that it is entirely apparent that these cases must rest without the possibility of ever being blessed with the official seal of the Patent Office.

This unwritten history embraces also many inventions of great practical utility which lie buried in secrecy for reasons known only to their authors; they tell oftentimes the sad story of want, privation, and suffering, and sleep for years only to be resurrected after some more fortunate independent inventor has succeeded in reaching the desired goal.

There is very much of interest and importance in this secret history, and were the records of abandoned cases made public, as in my opinion they should be, the art would receive much that is valuable which will now remain a sealed book forever.

In conclusion, I beg to call attention to the very important position which the Patent Office records hold in the written history of the art and to the fact that our patent system is the best which the civilized world ever knew.

We stand to-day at the head of the civilized world as being the one nation noted for its great inventions. Our ingenuity as a nation of inventors is far-famed. It is due not alone to a peculiarly ingenious people, but rather to the fact that the humblest citizen realizes that for a mere pittance, he can patent and secure from his government a monopoly of his invention for a limited time.

The system has stimulated inventive genius wherever it offers itself, and to-day we find ourselves a nation of educated people

whose homes are surrounded with all the comforts which civilization can give us.

Education has joined issue with ingenuity and the two march hand in hand, each stimulating the other and each vieing with the other in seeking to see where and how the most can be done to elevate the human race to the plane of an all-wise Creator.

Who can tell where it will end? Who can tell what will be the future of such a nation?

BOOK NOTICE.

PRINCIPLES OF ECONOMY IN THE DESIGN OF METALLIC BRIDGES. By Chas. B. Bender. New York: John Wiley & Sons.

To those engineers who are dissatisfied with the meagre efforts heretofore made toward solving the problem of economically proportioning truss-bridges, this work will perhaps be of interest. Mr. Bender begins with criticising the so-called Rankine formula for the ultimate strength of struts, and shows clearly an anomaly in it. He proposes as a remedy, however, another formula equally empirical, founded upon scattered data. The fact is that, when dealing empirically with a scientific subject, every experimenter arrives at an expression of his own, which he maintains against all comers. Of course, better rough approximations by empiricism than guesses; but no satisfactory results will ever be had until the laws in operation have been discovered and measured. Patient experiment and study alone will reveal these laws; they may escape our grasp for a while, yet only for a while. In regard to rupture by tension and compression, such complex action occurs apparently after passing the limit of elasticity, that some engineers have turned their attention solely to fixing this limit, and making their factors of safety depend upon it rather than upon ultimate strength. The theory of elasticity has been much assailed, usually by those who are not aware of its possibilities, still it has survived all attacks. It may, with judgment, be applied to columns quite as well as to solid girders. What takes place when elasticity fails is, in practice, of little interest to the engineer. A structure is already useless if the strains through it reach the limit of elasticity of its material. Besides, the study of material under strains is much simpler below this limit than above it, and experiments confined to elasticity are more reliable than when extended to ultimate strength.

After a rather obscure article on the effects of repeated strains on tension members, the author enters really upon his subject. He obtains expressions for the volume of material in various kinds of trusses, under the favorable supposition of equal loads at their apices, and by these expressions deduces certain laws of economical proportion. He, moreover, compares the different shapes and kinds of trusses in regard to their consumption of material, and grows enthusiastic over American systems of bracing. Next

follows a long discusion of the economy of cantilever bridges, and of their possibilities for the enormous spans in contemplation through their use. The suspension bridge, also, is discussed with special reference to its stiffening girder. The lateral bracing of truss bridges receive some consideration, and finishes the work. In an appendix is reprinted, from the *Railroad Gazette*, the account of some experiments on steel and iron girders conducted in Europe.

With few exceptions the mathematics employed by Mr. Bender are simple; although they may prove objectionable to those who look upon algebraic symbols as stumbling blocks. Much information, didactic and descriptive, is scattered through the book; and very interesting are the historical details connected with the forms and improvements of bridges. The labor performed in Germany especially is reviewed by Mr. Bender. We recommend this work to the profession. C. A. E.

LIST OF BOOKS

ADDED TO THE LIBRARY FROM MARCH 1, 1885.

Freeman, H. C. The La Plata Mountains. 1885.
Presented by American Institute of Mining Engineers.

Frazer, Persifor. General Notes on the New Orleans Industrial and Cotton Exhibition. 1885. Presented by the Author.

Fulton, J. Source and Behavior of Fire-Gas in the Johnstown Mines. Transactions of American Institute of Mining Engineers. 1885.
Presented by the Institute.

Gardner, E. C. Home Interiors. Boston, 1878.

Gardner's Monthly. Vols. 1–4 and 14–16 inclusive. Philadelphia, 1859–62 and 1872–74.

Gardner's Monthly and Horticultural Advertiser. Published by Chas. H. Marot. Vols. 5–13 inclusive, and No. 12 of Vol. 14. Philadelphia, 1863–72. Presented by the Publisher, and Completing the Set.

Gatewood, R. Theory to Explain the Cause of Hard Centres in Steel Ingots. 1885. Presented by the American Institute of Mining Engineers.

Geikie, A. Geological Sketches. New York, 1882.

Génie Civile. Vol. 6. Paris, 1884.

Genth, F. A., and G. Vom Rath. Contributions from the Laboratory of the University of Pennsylvania. No. 23. Vanadates and Iodyrite, from Lake Valley, Sierra Co., New Mexico. Presented by the Author.

Geological Survey of Canada. Report of Progress for 1882–84, and Catalogue of Canadian Plants. Part 2. Gamopetalœ. By John Macoun. Montreal, 1884–85. Presented by the Survey.

Geological Survey of India. Memoirs. Palæontologia Indica. Series 4, Vol. 1, Part 4; Series 10, Vol. 3, Part 5; Series 13, Part 1, Fas. 3 and 4; Series 14, Vol. 1, Part 3. Presented by the Survey.

Geological Survey of India. Memoirs. Vol. 21, Parts 1 and 2, and Vol. 22. Calcutta. Presented by the Survey.

Geological Survey of New Jersey. Annual Report of State Geologist for the Year 1884. Presented by the State Geologist.

Geological Survey of New Jersey. A Preliminary Catalogue of the Flora of New Jersey. Compiled by N. L. Britton. New Brunswick, 1881. Presented by Professor G. H. Cook, State Geologist.

Georgia Historical Society. Savannah, Ga. Constitutions and By-Laws and Lists of Members. Savannah, 1859, 1871, 1873.
 Dedication of Hodgson Hall. Proceedings. 1876.
 Address on Sergeant Wm. Jasper. By C. C. Jones.
 Harden, E. J., Proceedings, etc., Commemorative of.
 Reply to a Resolution of the Georgia Historical Society.
 Collections of Georgia Historical Society. Part 1, Vol. 3.
 Anniversary Address Delivered in Hodgson Hall, 1881.

Georgia Historical Society. Savannah, Ga. Collections. Vols. 2, 3 and 4. Savannah, 1842–78, and History of Georgia. By Wm. Bacon Stevens, M. D. New York, 1847–59. Presented by the Society.

German Society of the City of New York. One Hundred and first Annual Report. 1885. Presented by the Society.

Gilks, Thos. Art of Wood Engraving. London, 1871.

Glühlicht, Das. Vol. 27. Elektro-Technische Bibliothek. Wien.

Grain, Report of. Department of Agriculture Bureau of Statistics. U. S. April, 1885. Presented by the Department.

Grand Trunk Railway Company of Canada. Report of the Directors and Statement of Accounts for July–December, 1884. Presented by the Company.

Grant, Geo. B. Hand-book on the Teeth of Gears with Odontographs. Boston: Author, 1885. Presented by the Author.

Half Tints: Table D'Hôte and Drawing-room. New York, 1867.

Hartford, Conn. Board of Water Commissioners. Thirtieth and Thirty-first Annual Reports. Hartford, 1884–85. Presented by the Board.

Hartwig, Dr. G. The Polar World. New York, 1869.

Harvard College. Annals of the Astronomical Observatory. Parts 1 and 2 of Vol. 14. Cambridge, 1884–85. Presented by the College.

Harvard College. Thirty-ninth Annual Report of the Director of the Astronomical Observatory. By E. C. Pickering. Cambridge, Mass., 1885. Presented by E. C. Pickering.

Health Exhibition, International. London, 1884.
 Conferences, Catalogues, Hand-books, Guides, Lectures, Programmes.

Henry Statue, Addresses at the Unveiling of, at Washington. April 19, 1883. By Chief-Justice Waite and Noah Porter. Washington, 1884. Presented by the Smithsonian Institute.

Hexamer, C. John. Dwelling House Fires: their Causes and Prevention, etc. Philadelphia, 1885. Presented by the Author.

Hexamer, C. John. Fire Hazards in Textile Mills, Mill Architecture, and Means for Extinguishing Fire. Philadelphia, 1885. Presented by the Author.

Himes, C. F. Actinism. Lecture Delivered at International Electrical Exhibition, 1884.
Reprinted from the JOURNAL OF THE FRANKLIN INSTITUTE, 1885.

Hunt, R. W. Clapp-Griffiths Process. Transactions of American Institute of Mining Engineers, 1885. Presented by the Institute.

Hydrographic Office, U. S. Pilot Charts for January–October, 1884, and April, 1885. Presented by the Chief of the Office.

Illinois, Department of Agriculture State of. Transactions. Vol. 21. 1883. Springfield, 1884.

Illinois State Board of Health. Reports of Proceedings, February 5–7, 1885. Practical Recommendations for Exclusion and Prevention of Asiatic Cholera in North America. By J. H. Rauch, Secretary.
Presented by the Board.

Illinois State Board of Health. Second–Sixth Annual Reports. Springfield 1881–84. Presented by the Secretary.

Illinois State Laboratory of Natural History. Normal, Illinois. Vol. 2, Art. 1. Descriptive Catalogue of the North American Hepaticæ, North of Mexico. By L. M. Underwood. 1884. Art. 2. Description of new Illinois Fishes. By S. A. Forbes. Presented by the State Laboratory.

Illustrated Magazine of Art. Containing Selections from the Various Departments of Painting, Sculpture, Architecture, History, etc. Two volumes in one. New York, 1853.

India. Report on the Meteorology, for 1882. By H. F. Blanford. Eighth Year. Calcutta, 1884.
Presented by the Meteorological Dept. of the Government of India.

Indiana. Bureau of Statistics. Third–Sixth Annual Reports of the Chief Completing the Set. Presented by the Chief.

Indiana. First Annual Report of State Board of Health for 1882. Indianapolis, 1883. Presented by Dr. T. M. Stevens, Secretary.

Indiana. Department of Geology and Natural History. Twelfth–Fourteenth Annual Reports. John Collett, State Geologist. Indianapolis, 1883–84.
Presented by the State Geologist.

Indiana State Board of Agriculture. Annual Reports for 1854 and 71. Vol. 1. Indianapolis.

Indiana State Board of Agriculture. Annual Reports for 1883–84. Indianapolis. Presented by the Board.

Inland Architect and Builder. Vols. 4–5. Chicago, 1884–85.
Presented by the Inland Publishing Company.

Institution of Civil Engineers. Ireland. Transactions. Vol. 14. Dublin, 1884.

Institution of Civil Engineers. London. Index to Proceedings. Vols. 1–58. 1837–79. London, 1885. Presented by the Institution.

Institution of Civil Engineers, London. Minutes of Proceedings. Vol. 79. London, 1885. Presented by the Institution.

Institution of Mechanical Engineers. Proceedings. London, 1884.

Instituto y Observatorio de Marina de San Fernando. Anales. Seccion 2a. 1883. Presented by the Institute.

Internal Affairs, Penna. Annual Report of the Secretary. Part 3. Industrial Statistics. Harrisburg, 1884.

Internal Commerce, U. S. Report. By Joseph Nimmo, Jr. Washington, 1885. Presented by the Bureau of Statistics, Treasury Department.

Iowa State Historical Society. Fifth–Eighth and Tenth–Fourteenth Annual Reports. Des Moines, 1866–83. Presented by the Society.

Iron. Vols. 23–24. London, 1884.

Iron and Steel. On the Modifications of Tensile Strength and Ductility which they Undergo when Heated. Translated by Chief Engineer Isherwood.

Italy. Subject-Matter Index of Patents for Inventions. 1848–82. Translated, Compiled and Published Under Authority of the Commissioner of Patents. Washington, 1885. Presented by the U. S. Patent Office.

Ives, F. E. Isochromatic Photography. Reprinted from the JOURNAL OF THE FRANKLIN INSTITUTE. May, 1885.

Jahres-Bericht über die Leistungen der Chemischen Technologie. 1884. Leipzig, 1885.

Jeans, W. T. The Creators of the Age of Steel. New York, 1884. Purchased with the Legacy of B. H. Moore.

Johns Hopkins University. Register, 1884–85. Baltimore, 1885. Presented by the University.

Johnson, Wm. W. Curve Tracing in Cartesian Coördinates. New York. J. Wiley & Son. 1884. Purchased with the Legacy of B. H. Moore.

Journal of Gas Lighting. Vol. 44. London, 1884.

Journal of Pharmacy. Vol. 14. Fourth Series. Philadelphia, 1884.

Journal of Science. Third Series, Vol. 6. London, 1884.

Journal of the Chemical Society. Vol. 43. London, 1883.

JOURNAL OF THE FRANKLIN INSTITUTE. Vol. 88. Third Series. Philadelphia, 1884.

Journal of the Statistical Society. Vol. 47. London, 1884.

K. K. Geographischen Gesellschaft. Mittheilungen, 1884. Wien, 1885. Presented by the Society.

K. K. Geologischen Reichsanstalt. Jahrbuch. 1884. Vol. 34.
Verhandlungen, Nos. 13–18. 1884.
Carbon—Flora der Schatzlarer Schichten. Wien, 1885.
Presented by K. K. Geologischen Reichsanstalt.

Kansas State Agricultural College. Report of Experiments. 1884. Manhattan, 1885.
Catalogue of Pure-Bred Cattle. 1884.
The Industrialist. May 9, 1885.
Catalogue of the College. 1884 85. Presented by Lewis S. Ware.

ERRATUM.

Article—Wahl: "Summary of Engineering Progress," etc.

Page 305, third line from bottom, for "Birmingham" *read* "Birkenhead."

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXI. JUNE, 1886. No. 6.

AN ACCOUNT OF THE COMPARABLE EXPERIMENTS MADE IN THE NEW YORK NAVY YARD, BY CHIEF ENGINEERS THEODORE ZELLER AND GEORGE P. HUNT, OF THE U. S. NAVY, TO ASCERTAIN THE ECONOMIC EFFECT OF USING IN A NON-CONDENSING ENGINE SATURATED STEAM ALONE, AND OF USING IT MIXED WITH COMPRESSED HOT AIR ACCORDING TO THE SYSTEM OF MR. E. M. STRANGE.

BY CHIEF ENGINEER ISHERWOOD, U. S. Navy.

The following experiments were made in the New York Navy Yard on the fifth of August, 1885, by a board composed of Chief Engineers Theodore Zeller and George P. Hunt, of the United States Navy, with an apparatus submitted by Mr. E. M. Strange, for the purpose of ascertaining how much economic gain, if any, attended the use in a non-condensing steam engine of a mixture of saturated steam, and of air compressed to the pressure of the steam, and containing its heat of compression.

The engine to which the apparatus was attached, was an old

one in the boiler shop of the engineering department, and out of use. Its work, when in use, was to drive the shafting from which power was taken to operate the various tools employed in boiler-making, and a small, highly-geared centrifugal blower, which furnished air to the forges of the shop. During the experiments, the tools were not connected with the shafting, and the discharging nozzle of the blower was partly closed, so that the work done by the engine was the forcing of air through the contracted nozzle of the blower, and overcoming the friction of the shafting. Consequently, equal numbers of double strokes made by the piston of the engine in equal times, performed equal work.

The engine and apparatus with which the experiments were made had the following dimensions:

Number of steam cylinders, ...	1·
Diameter of the steam cylinder, ...	12 inches.
Diameter of the piston rod on one side of the piston, ...	1⅝ inches.
Diameter of the piston rod on the other side of the piston, ...	1¼ inches.
Net area of the piston, exclusive of areas of piston rods, ...	111·4471 square inches.
Stroke of the piston, ...	30· inches.
Space displacement of the piston per stroke, .	1·9348455 cubic feet.
Diameter of the air compressor, ...	9· inches.
Diameter of the piston rod of the air compressor (one side of piston only), ...	1¼ inches.
Net area of the piston of the air compressor, exclusive of area of piston rod, ...	63·0038 square inches.
Stroke of the piston of the air compressor, . . .	30. inches.
Space displacement of the piston of the air compressor per stroke, ...	1·093816 cubic feet.
Number of air inlet valves to the air compressor,	1·
Diameter of the air inlet valve, ...	3· inches.
Number of air outlet valves to the air compressor,	1·
Diameter of the air outlet valve, ...	3· inches.
Net area of the air outlet and inlet valves, exclusive of stem, ...	6·96 square inches.
Face of the piston of the air compressor, . . .	3½ inches.
Thickness of metal of the air compressor and of its reservoir, ...	¾ inch.
Ratio of the space displacement of the piston of the air compressor to that of the piston of the steam cylinder, ...	0·565325

Ratio of the space displacement of the piston of the steam cylinder to that of the piston of the air compressor, ... 1·768895

The steam cylinder is horizontal and direct acting. It has four valves, two at each end, one of which is for the admission of steam and the other for the exhaust. All the valves are plain plates of metal, and are worked by one eccentric in the ordinary manner. The steam valves act also as cut-off or expansion valves, being tripped by cams at any desired portion of the stroke of the steam piston, and brought to position over the steam port by stiff springs. All the valves work vertically. The steam valves are at the upper side, and the exhaust valves are at the lower side of the cylinder.

The pressure of the steam in the valve chest is upon the backs of the steam valves, and the pressure of the steam in the cylinder is upon the cylinder side of the exhaust valves, while the atmospheric pressure is upon their opposite side. The steam piston is packed by rings and springs in the usual manner.

Previous to commencing the experiments, the piston and valves of the steam cylinder were examined and put in proper working order.

The steam cylinder was neither steam jacketed, nor lagged, nor protected in any way from the radiation of heat. It was situated, however, in a closed room, which prevented air currents from passing over it. The main shaft of the engine carried a light fly wheel.

The air compressor, which was double-acting, was a plain cast iron cylinder placed horizontally behind the steam cylinder, and having its axis in the same straight line with that of the latter. The piston was of cast iron, with two recesses surrounding its face, for the reception of the packing rings and springs which made it air-tight. The piston rod of the air compressor was extended through the back end of the steam cylinder and secured to the piston of the latter, so that, practically, the pistons of the steam cylinder and of the air compressor were on the same rod, and, of course, made stroke for stroke, the piston of the air compressor commencing to compress the air at the same moment that the steam cylinder received steam, both pistons being at the end of their stroke.

By this arrangement, the resistance to the piston of the air compressor increased, while the pressure of the steam upon the piston of the steam cylinder decreased, so that when the two pistons reached the end of their stroke, the resistance against the first was at a maximum, while the pressure upon the last was at a minimum. When the steam was cut off at much less than half the stroke of the piston of the steam cylinder the engine would stop, because the resistance to the piston of the air compressor was then greater than the steam pressure upon the piston of the steam cylinder, so that, notwithstanding the momentum of the fly wheel, the engine gradually came to a state of rest. Of course, this might have been avoided by interposing a lever between the two pistons that would have reversed their movements and made the maximum air compression coincident with the maximum steam pressure upon the piston of the steam cylinder.

Each head of the air compressor was double, the space between the two shells serving as air passages for the incoming and outgoing air. Each end had a receiving and a delivering valve; these valves were single poppet or single disc valves, working horizontally and seating in the inner shell.

The air compressor was concentrically surrounded by a cylindrical reservoir of the same length, and between which and the compressor there was a space of one and one-fourth inches in the clear, which space communicated with the air discharging valves in the ends of the compressor. From the centre of this reservoir, on top, a three-inch interior diameter pipe carried the compressed air to the steam pipe of the engine, debouching into the latter between the throttle valve and the valve chest of the steam cylinder. A short branch from this three-inch diameter air pipe was fitted with a three-inch diameter cock, whereby the air from the compressor was discharged into the atmosphere when the engine was operated by steam alone, the cock being then open. In the three-inch diameter air pipe, and between this branch and the steam pipe, there was a three-inch diameter poppet check valve, whose office was to prevent the steam in the steam pipe from flowing into the atmosphere through the cock when the latter was open.

When the engine was in operation, the air was always being compressed in the compressor and discharged, whether the engine was used with combined steam and air, or with steam alone, so

that in the latter case provision had to be made for its discharge into the atmosphere.

The smallest area for the passage of the compressed air into the steam pipe below the throttle valve, was 3·1416 square inches, being the area due to a diameter of two inches Through this area, equal to one-twentieth of the area of the piston of the compressor, all the compressed air was forced by the latter.

When the engine was in operation with combined air and steam, the pressure in the valve chest of the steam cylinder, in the steam pipe below the throttle valve, in the air pipe from compressor to cylinder, in the reservoir of the air compressor, and in the compressor after the delivery valve opened, was the same, excepting the slight variations in the statical equilibrium made dynamically by the current of the gases.

The experiments were four in number, constituting two pairs of comparable tests with different cylinder pressures, piston speeds and measures of expansion. The largest measure of expansion which could be used was that due to the intended cutting off of the steam at half stroke of the piston. The other measure of expansion was that due to the intended cutting off of the steam at seven-tenths of the stroke of the piston from the commencement.

With each intended measure of expansion, an experiment was first made with combined air and steam, and a certain position of the tripping gear for cutting off the steam. The steam pressure in the boiler was maintained invariable from beginning to end of the experiment; and the throttle valve, having been adjusted to give the intended number of double strokes of piston per minute, remained unaltered during that test. After the experiment commenced, no change of any kind was made in any of the conditions up to its end.

Immediately after the conclusion of the experiment with the combined air and steam, a comparable test was made with steam alone, the position of the cut-off tripping mechanism remaining unchanged from the last experiment, so as to secure as nearly as possible the same measure of expansion for the two cases In this comparable trial, the steam in the boiler was maintained at exactly the same pressure as before, but the throttle valve was altered until the engine piston made the same number of double strokes per minute as before.

During the two experiments with the combined air and steam, indicator diagrams were taken simultaneously every three minutes from both ends of the steam cylinder and from both ends of the air compressor. The indicators remained permanently in place and the same springs were employed throughout. When the experiments were made with steam alone, the indicator diagrams were taken every three minutes from both ends of the steam cylinder only; none being taken from the air compressor because repeated trials showed no sensible pressure therein when the cock in the branch pipe was open to the atmosphere.

Before commencing an experiment, the engine was operated sufficiently long to attain its normal state for the conditions.

The boiler was greatly too large for the engine as loaded, and as the steam in all cases was very much throttled, there was not the slightest trace of foaming or priming. The pressure in the boiler was maintained throughout by a skilled fireman at exactly sixty pounds per square inch above the atmosphere, by opening and closing the furnace door as the pressure tended to rise above or fall below the limit.

A very good spring gauge gave the mean pressure in the valve chest of the steam cylinder.

An excellent thermometer was inserted into the centre of the reservoir of the air compressor, and a duplicate thermometer was inserted into the valve chest of the steam cylinder. These thermometers were screwed into their respective places, so that their naked bulbs and the lower part of their stems were in direct contact with the gases.

The standard Navy Yard barometer gave the pressure of the atmosphere.

The pressures and temperatures were observed and recorded every three minutes.

In commencing an experiment with the combined air and steam, the exact position of the water level in the boiler was marked on the glass water-gauge of the latter, and at the expiration of one hour during which the independent steam pump which fed the boiler was stopped and the feed check valve screwed down, the water level in the boiler was again exactly marked on the gauge. The weight of steam evaporated in the boiler and used in the cylinder during the experiment, was that which was due to the

weight of water between the two levels, the steam pressure being maintained invariable from first to last. The number of cubic feet of water contained between these levels, was ascertained when the boiler was cold by filling it from one to the other by means of a measure of carefully ascertained capacity. The number of pounds of water consumed in any of the cases, was obtained by multiplying the number of cubic feet as above ascertained by the weight of water per cubic foot at the temperature due to the pressure of sixty pounds per square inch above the atmosphere.

The number of double strokes of piston made by the engine, was taken by a counter. The temperature of the air in the engine room, was taken by a thermometer placed near the inlet of the air compressor, but shielded from the radiant heat of surrounding bodies, so as to give the temperature of the air as it entered the compressor.

The data and results of the experiments will be found in the following table, in which the data are the means of all the observations recorded and of all the indicator diagrams taken. For convenience of reference, the columns of the table have been lettered, the quantities grouped and the lines containing them numbered.

(*See Table.*)

The table contains the data and results of the two pairs of experiments made ; each pair being the comparable tests with saturated steam alone, and with the same combined with air compressed to the pressure of the steam and retaining the heat of compression.

The columns containing the experimental quantities are lettered *A*, *B*, *C* and *D*. Experiments *B* and *D* were made with saturated steam alone, but with different pressures, measures of expansion, and double strokes of the engine piston per minute. Experiments *A* and *C* were made with saturated steam combined with air compressed to the pressure of the steam and retaining the heat of compression. The intention was that the measure of expansion with which the gases were used, and the number of double strokes made per minute by the piston of the engine, should be exactly the same in experiments *A* and *B* which were to be strictly comparable ; and also in experiments *C* and *D* which likewise were to be comparable. This intention was realized as nearly as the nature of the valve gear of the engine would permit, and sufficiently near

to give correct results, the economic differences due to the small variations from the intended conditions being too small sensibly to affect the determinations.

In all the experiments, the steam was used without condensation.

Line 1 gives the time at which each experiment began.

Total Quantities.—Line 2 gives the duration of the experiment in minutes and seconds; and lines 3 and 4 give, respectively, the number of double strokes made by the engine piston, and the number of pounds of feed water consumed, during the time on line 2.

Engine.—Line 5 gives the number of double strokes made by the engine per minute, the quantities being the quotients of the division of those on line 3 by the number of minutes on line 2.

Line 6 gives the steam pressure in the boiler in pounds per square inch above the atmosphere. This was in all cases maintained invariably at sixty pounds.

Line 7 gives the position of the throttle valve as greatly closed in all four experiments. In no two experiments, however, had it the same opening, but even when at the widest, there was still a difference of nearly twenty pounds per square inch between the boiler pressure and the pressure on the steam piston at the commencement of its stroke. The throttle valve was a screw disc and remained unchanged during each experiment.

Line 8 gives the mean pressure in the valve chest of the steam cylinder in pounds per square inch above the atmospheric pressure. The pressure oscillated during each stroke of the steam piston.

Line 9 gives the pressure of the atmosphere in pounds per square inch above zero. This pressure added respectively to the pressures on lines 6 and 8, would give the pressures in the boiler and in the cylinder valve chest above zero.

Line 10 gives the number of pounds of feed water consumed per hour, the quantities being the quotients of the division of those on line 4 by the number of hours on line 2.

Temperatures.—Line 11 gives the mean temperature in the valve chest of the steam cylinder as observed on the thermometer inserted therein. In experiments *B* and *D*, this temperature is that of saturated steam of the pressure on line 8; but in experiments *A* and *C*, it is that which is therein due to the combined steam and air used in them.

Table containing the Data and Results of the Comparable Experiments, made by Chief Engineers Theodore Zeller and George P. Hunt, of the United States Navy, on the 5th of August, 1885, in the New York Navy Yard, for the Purpose of Determining the Relative Economy of Using Saturated Steam alone, and of Using it Mixed with Compressed Hot Air as Produced by the Apparatus of Mr. E. M. Strange and according to his Method.

		... expended upon the air in the air compressor,	10·932350	....	22·107419	....
36		Horses-power developed by the expanding steam in the steam cylinder, after the closing of the cut-off,	5·757779	3·439406	13·124619	7·979446
37	Economic Results.	Number of pounds of feed water consumed per hour per indicated horses-power developed by the steam cylinder less the indicated horses-power expended upon the air in the air compressor,	129·666605	133·651683	105·793660	104·897251
38		Number of pounds of feed water consumed per hour per total horse-power developed by the steam cylinder less the indicated horses-power expended upon the air in the air compressor,	45·839795	45·985574	40·549642	39·763378
39	Weight of Steam accounted for by the Indicator.	Number of pounds of steam present in the steam cylinder at the point of cutting off the steam, calculated from the pressure there,	....	459·471009	....	499·684150
40		Number of pounds of steam present in the steam cylinder at the end of the stroke of its piston, calculated from the pressure there,	....	481·231508	....	524·730053
41		Number of pounds of steam condensed in the steam cylinder to furnish the heat transmuted into the total herses-power developed by the expanded steam alone,	....	8·981397	....	21·102064
42		Sum of the two immediately preceding quantities,	....	490·212905	....	545·832117
43	Difference between the Weight of Water vaporized in the Boiler and the Weight of Steam accounted for by the Indicator.	Difference, in pounds, between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator in the steam cylinder at the point of cutting off the steam,	....	316·704443	....	399·196860
44		Difference, in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the steam cylinder at the point of cutting off the steam,	....	40·803203	....	44·410428
45		Difference, in pounds, between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator in the steam cylinder at the end of the stroke of its piston,	....	285·962547	....	353·048793
46		Difference, in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the steam cylinder at the end of the stroke of its piston,	....	36·842514	....	39·276481

to give correct results, the economic differences due to the small variations from the intended conditions being too small sensibly to affect the determinations.

In all the experiments, the steam was used without condensation.

Line 1 gives the time at which each experiment began.

Total Quantities.—Line 2 gives the duration of the experiment in minutes and seconds; and lines 3 and 4 give, respectively, the number of double strokes made by the engine piston, and the number of pounds of feed water consumed, during the time on line 2.

Engine.—Line 5 gives the number of double strokes made by the engine per minute, the quantities being the quotients of the division of those on line 3 by the number of minutes on line 2.

Line 6 gives the steam pressure in the boiler in pounds per square inch above the atmosphere. This was in all cases maintained invariably at sixty pounds.

Line 7 gives the position of the throttle valve as greatly closed in all four experiments. In no two experiments, however, had it the same opening, but even when at the widest, there was still a difference of nearly twenty pounds per square inch between the boiler pressure and the pressure on the steam piston at the commencement of its stroke. The throttle valve was a screw disc and remained unchanged during each experiment.

Line 8 gives the mean pressure in the valve chest of the steam cylinder in pounds per square inch above the atmospheric pressure. The pressure oscillated during each stroke of the steam piston.

Line 9 gives the pressure of the atmosphere in pounds per square inch above zero. This pressure added respectively to the pressures on lines 6 and 8, would give the pressures in the boiler and in the cylinder valve chest above zero.

Line 10 gives the number of pounds of feed water consumed per hour, the quantities being the quotients of the division of those on line 4 by the number of hours on line 2.

Temperatures.—Line 11 gives the mean temperature in the valve chest of the steam cylinder as observed on the thermometer inserted therein. In experiments *B* and *D*, this temperature is that of saturated steam of the pressure on line 8; but in experiments *A* and *C*, it is that which is therein due to the combined steam and air used in them.

Table containing the Data and Results of the Comparable Experiments, made by Chief Engineers Theodore Zeller and George P. Hunt, of the United States Navy, on the 5th of August, 1885, in the New York Navy Yard, for the Purpose of Determining the Relative Economy of Using Saturated Steam alone, and of Using it Mixed with Compressed Hot Air as Produced by the Apparatus of Mr. E. M. Strange and according to his Method.

Number of Line			Comparable Experiments. The Piston-speed, the Point of Cutting off the Steam, and the Load intended to be the same		Comparable Experiments. The Piston-speed, the Point of Cutting off the Steam, and the Load intended to be the same.	
			Air and Steam Combined. *A.*	Steam Alone. *B.*	Air and Steam Combined. *C.*	Steam Alone. *D.*
1		Time of commencing experiment,	10 50 A. M.	12·12 P. M.	1·56 P. M.	3·13 P. M.
2	Total Quantities	Duration of experiment in consecutive minutes and seconds,	60 00	59·30	60·00	60 45
3		Total number of double strokes made by the piston of the engine,	2978	2927·	3694·	3736·
4		Total number of pounds of feed water consumed,	776·175452	776·175452	898·880910	898·880910
5	Engine.	Number of double strokes made per minute by the piston of the engine,	49·633333	49·19328	61·566667	61·49794
6		Steam pressure in the boiler in pounds per square inch above the atmosphere,	60·	60	60·	60
7		Position of the throttle valve,	Greatly closed.	Greatly closed.	Greatly closed.	Greatly closed.
8		Pressure (mean) in the valve chest of the steam cylinder in pounds per square inch above the atmosphere,	24·00	12·25	35·00	20·80
9		Pressure of the atmosphere in pounds per square inch above zero,	14·69	14·69	14·69	14·69
10		Number of pounds of feed water consumed, per hour,	776·175452	782·697935	898·880910	887·783615
11	Temperatures.	Temperature in degrees Fahrenheit in the valve chest of the steam cylinder,	240·	244·	262·	260·
12		Temperature in degrees Fahrenheit due to the pressure in the valve chest of the steam cylinder, supposing the pressure there to be that of saturated steam,	265·1	244·2	280·5	260·0
13		Temperature in degrees Fahrenheit of the air in the reservoir of the compressor,	133·0	. . . .	190·0	. . . .
14		Temperature in degrees Fahrenheit of the air in the engine room,	90·0	94·0	98·0	102·0
15	Steam Pressures in Steam Cylinder.	Fraction completed of the stroke of the piston of the steam cylinder when the steam was cut off,	0·700	0·755	0·512	0·548
16		Fraction completed of the stroke of the piston of the steam cylinder when the steam was cushioned,	0·860	0·885	0·[illegible]66	0·879
17		Pressure in pounds per square inch above zero in the steam cylinder at the commencement of the stroke of its piston,	41·48	28·64	55·14	36·20
18		Pressure in pounds per square inch above zero in the steam cylinder at the point of cutting off the steam,	30·30	21·05	39·39	24·87
19		Pressure in pounds per square inch above zero in the steam cylinder at the end of the stroke of its piston,	22·08	16·50	22·11	14·00
20		Pressure in pounds per square inch above the atmosphere in the steam cylinder of the back pressure against the piston, exclusive of the cushioned back pressure,	0·50	0·50	0·50	0·50
21		Mean indicated pressure on the piston of the steam cylinder in pounds, per square inch,	15·90	7·05	21·00	8·15
22		Mean total pressure on the piston of the steam cylinder in pounds, per square inch,	28·96	20·49	34·15	21·50
23		Mean pressure of the expanding steam in the steam cylinder in pounds per square inch above zero, after the cut-off valve closed,	22·90	16·90	25·87	17·00
24	Air Pressures in Air Compressor.	Fraction completed of the stroke of the piston of the air compressor when its delivery valve opened,	0·533	. . . .	0·419	. . . .
25		Pressure in pounds per square inch above the atmosphere in the air compressor at the commencement of the stroke of its piston,	0·00	. . . .	0·00	. . . .
26		Pressure in pounds per square inch above the atmosphere in the air compressor when its delivery valve opened,	20·00	. . . .	32·49	. . . .
27		Pressure in pounds per square inch above the atmosphere in the air compressor at the end of the stroke of its piston,	28·70	. . . .	45·09	. . . .
28		Mean indicated pressure on the piston of the air compressor in pounds per square inch,	15·49	. . . .	22·69	. . .
29		Mean pressure of the air during compression in the air compressor in pounds per square inch above the atmosphere; that is to say, the mean pressure of the compressed air between the commencement of the stroke of the piston of the air compressor and the point at which its delivery valve opened,	7·712	. . . .	11·203	. . . .
30	Horses-power.	Indicated horses-power developed by the steam cylinder,	13·325865	5·856252	21·831810	8·463364
31		Total horses-power developed by the steam cylinder,	24·271512	17·020510	35·502681	22·326665
32		Indicated horses-power expended upon the air in the air compressor,	7·339162	. . . .	13·335262	. . . .
33		Horses-power expended in compressing the air in the air compressor; that is to say, the horses-power developed in compressing the air in the air compressor from the commencement of the stroke of its piston to the point at which its delivery valve opened,	1·947553	. . . .	2·758770	. . . .
34		Indicated horses-power developed by the steam cylinder less the indicated horses-power expended upon the air in the air compressor,	5·986703	. . . .	8·496548	. . . .
35		Total horses-power developed by the steam cylinder less the indicated horses-power expended upon the air in the air compressor,	16·932350	. . . .	22·167419	. . . .
36		Horses-power developed by the expanding steam in the steam cylinder, after the closing of the cut-off,	5·757779	3·439406	13·124619	7·979446
37	Economic Results.	Number of pounds of feed water consumed per hour per indicated horses-power developed by the steam cylinder less the indicated horses-power expended upon the air in the air compressor,	129·666605	133·651683	105·793660	1[illegible]4·897251
38		Number of pounds of feed water consumed per hour per total horse-power developed by the steam cylinder less the indicated horses-power expended upon the air in the air compressor,	45·839795	45·985574	40·549642	39·763378
39	Weight of Steam accounted for by the Indicator.	Number of pounds of steam present in the steam cylinder at the point of cutting off the steam, calculated from the pressure there,	. . . .	459·471009	. . . .	499·684[illegible]50
40		Number of pounds of steam present in the steam cylinder at the end of the stroke of its piston, calculated from the pressure there,	. . . .	481·231508	. . . .	524·730053
41		Number of pounds of steam condensed in the steam cylinder to furnish the heat transmuted into the total herses-power developed by the expanded steam alone,	. . . .	8·981397	. . . .	21·102064
42		Sum of the two immediately preceding quantities,	. . . .	490·212905	. . . .	545·832117
43	Difference between the Weight of Water vaporized in the Boiler and the Weight of Steam accounted for by the Indicator.	Difference, in pounds, between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator in the steam cylinder at the point of cutting off the steam,	. . . .	316·704443	. . . .	399·196860
44		Difference, in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the steam cylinder at the point of cutting off the steam,	. . . .	40·803203	. . . .	44·410428
45		Difference, in pounds, between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator in the steam cylinder at the end of the stroke of its piston,	. . . .	285·962547	. . . .	353·048793
46		Difference, in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the steam cylinder at the end of the stroke of its piston,	. . .	36·842514	. . . .	39·276481

Line 12 gives the temperature, according to Regnault, due to the pressure in the valve chest of the steam cylinder, supposing that pressure to be the pressure of saturated steam. In experiments *B* and *D*, in which saturated steam was used, the agreement between the observed temperature and Regnault's is exact, showing the accuracy of the instruments employed.

In experiments *A* and *C*, in which the mixture of steam and air was used, the pressure of the steam component in the valve chest is assumed to be that on line 8, and the temperature given on line 12 is Regnault's temperature for that pressure. This assumption supposes there was no mixing of the air and steam in the valve chest, and that the air delivered into the chest from the compressor remained there *en bloc*, the steam entering from the boiler occupying the remainder of the space *en bloc*. While the air was being delivered into the valve chest by the compressor, it excluded the entrance of steam therein, because the pressure of the entering air must, in order to enter, be necessarily greater than the pressure of the steam already within, the steam entering only after the entire charge of air had been received. On this assumption, the engine, during experiments *A* and *C*, was not operated by a *mixture* of steam and compressed air, but by steam and compressed air *successively* and *separately*, each of these fluids remaining distinct from the other and performing its work in succession. Hence, the observed temperature in the valve chest of the steam cylinder (line 11) should be determined by the temperature of the steam therein (line 12), and by the temperature of the compressed air (line 13), multiplied by their respective *times of occupation* of the valve chest, and the sum of the products divided by the sum of the times. A rough calculation will show that the observed temperature on line 12 is just what would be given by such a calculation.

When the facts are considered, that the air compressor delivers its compressed air into the valve chest against the valve chest pressure without interruption, excluding *en bloc* whatever opposes the incoming air, and that only after the mass of air is withdrawn by the steam cylinder from the valve chest can steam enter the latter from the boiler, and that the time any single charge of air and steam remains in the valve chest is extremely limited (0·6 second in experiment *A* and 0·5 second in experiment *C*), the

very small chance for any mixture of importance can be easily comprehended; and as the same conditions exist for the cylinder in these respects as for the valve chest, there is just as little chance for mixture there.

These experiments, therefore, were not, and could not be made under the conditions necessary to show whether any economy of steam could be effected by the use of *intimately mixed* air and steam. The *mixing*, absolutely essential and by which alone any economic gain could be accomplished, was entirely wanting; and how any mixing is to be produced, unless by bulky and inconvenient mechanical methods, is difficult to conceive.

If the valve chest contained a thorough mixture of the air and steam, then the total pressure therein (line 8) would be composed in part of the steam pressure and in part of the air pressure, in proportion to their respective bulks at that pressure; so that the steam pressure would be much less than the pressure on line 8, and the air pressure would also be much less, the sum of the two pressures making up the total on line 8; whereas, without mixing, both the steam and the air have the pressure on line 8.

With a thorough mixture of the air and steam, the temperature in the valve chest would be very different from that on line 11, and would be determined by the respective weights of air and steam multiplied by their respective temperatures, and by their respective specific heats per unit of weight, the sum of the final products being divided by the aggregate weight of the air and steam, the quotient would be the temperature in the valve chest.

Line 13 gives the mean temperature of the air in the reservoir of the compressor, and line 14 gives the temperature of the air in the engine room near the receiving valves of the compressor. The temperature in the reservoir is that which is due to the heat of compression less the initial temperature, and, all other things being the same, is considerably affected by the more or less aqueous vapor in the air, the more the vapor the lower the temperature. Of course, the heat of compression, other things equal, results from and is in proportion to the mechanical work done upon the air during its compression.

Steam Pressures in the Steam Cylinder.—All the quantities on lines 15 to 23, both inclusive, are the means from all the indicator diagrams taken from the steam cylinder. Line 15 gives the fraction completed of the stroke of the steam piston when the steam

was cut off. The point of cutting off was taken to be that at which the convex curve of the throttled steam reversed into the concave curve of the expanded steam.

Line 16 gives the fraction completed of the return or exhaust stroke of the piston, when the exhaust port of the cylinder was closed and the cushioning or compression of the back pressure steam in the cylinder commenced. This compression was sufficient in all cases to fill the clearance and steam passage at one end of the cylinder to the valve chest pressure, so that the steam drawn from the boiler per stroke of piston was unaffected by those spaces.

Lines 17, 18 and 19 contain respectively the steam pressures in the cylinder in pounds per square inch above zero, at the commencement of the stroke of the piston, at the point of cutting off the steam, and at the end of the stroke of piston.

Line 20 contains the pressure of the back pressure against the piston, exclusive of the cushioned back pressure, in pounds per square inch above the atmosphere. The back pressure on line 20 operated against the piston for the fraction of its stroke given on line 16.

Line 21 gives the mean indicated pressure on the steam piston in pounds per square inch of its area.

Line 22 gives the mean total pressure on the steam piston above zero, in pounds per square inch of its area. If the quantity on line 20 be added to the atmospheric pressure on line 9, and the sum reduced in the ratio of the fraction on line 16 to unity, and added to the quantity on line 21, the sum will be the quantity on line 22.

Line 23 gives the mean pressure of the expanding steam in the cylinder in pounds per square inch above zero. That is to say, the mean pressure of the steam above zero for the portion of the piston stroke after the closing of the cut-off valve.

Air Pressures in the Air Compressor.—Lines 24 to 29, both inclusive, contain the air pressures in the air compressor as given by the mean of all the indicator diagrams taken from the compressor. There must be remembered that the air and steam pistons being upon the same piston rod, the compression of the air commenced simultaneously with the commencement of the stroke of the steam piston, and attained its maximum when the stroke of

that piston ended, so that the maximum air compression and the minimum steam pressure were simultaneous.

Line 24 gives the fraction of the stroke of the air piston completed when the delivery valve of the compressor opened and the compressed air commenced flowing into the reservoir of the compressor. This valve, of course, opened when the pressure in the compressor exceeded the pressure in the reservoir.

Line 25 gives the pressure in pounds per square inch above the atmosphere of the air in the compressor when the air piston commenced its stroke. This pressure was exactly the atmospheric pressure (line 9).

Lines 26 and 27 give, respectively, the air pressures in the compressor in pounds per square inch above the atmosphere, at the point in the stroke of the air piston at which the delivery valve opened, and at the end of the stroke of the piston. It will be observed that the latter pressure is considerably greater than the former, and is owing to the fact of a corresponding difference in the pressure in the reservoir at these times. This difference is caused by the variability in the draught upon the reservoir made by the piston of the steam cylinder, and its effect must be included in estimating the heat of compression.

Line 28 gives the mean indicated pressure in pounds per square inch of the air in the compressor upon its piston.

Line 29 gives the mean pressure in pounds per square inch above the atmosphere of the air in the compressor, between the commencement of the stroke of its piston and the point at which the delivery valve opened.

Horses-power.—Lines 30 to 36 contain the various horses-power developed by the piston of the steam cylinder, and also the horses-power expended upon the piston of the air compressor.

Line 30 gives the number of indicated horses-power developed by the steam cylinder, calculated for the pressure on line 21, and consequently inclusive in the cases of experiments *A* and *C* of the indicated horses-power expended upon the air in the air compressor as given on line 32.

Line 31 gives the number of total horses-power developed by the steam cylinder, calculated for the pressure on line 22, and consequently inclusive in the cases of experiments *A* and *C* of the indicated horses-power expended upon the air in the air compressor as given on line 32.

Line 32 gives the number of indicated horses-power expended upon the air in the air compressor, calculated for the pressure as given on line 28.

Line 33 gives the number of horses-power expended in compressing the air in the air compressor from the commencement of the stroke of its piston to the point in that stroke at which the delivery valve opened, calculated for the pressure on line 29. These horses-power are not the entire horses-power expended in air compression, because, after the delivery valve of the air compressor opened, there was a further compression of the air until the end of the stroke of the piston was reached, owing to the fact that the pressure in the reservoir into which the delivery valve opened was not constant, but was greater when the piston was at the end of its stroke than when it was at the point in its stroke at which the delivery valve opened. The temperature of the compressed air in the reservoir of the compressor was that which is due to the entire work of compression done upon the air.

Line 34 gives the indicated horses-power developed in the steam cylinder after subtracting the indicated horses-power expended upon the air in the compressor. The remainder is the true indicated horses-power developed by the steam cylinder during experiments *A* and *C*, and is obtained by subtracting the quantities on line 32 from those on line 30.

Line 35 gives the total horses-power developed in the steam cylinder after subtracting the indicated horses-power expended upon the air in the compressor. The remainder is the true total horses-power developed by the steam cylinder during experiments *A* and *C*, and is obtained by subtracting the quantities on line 32 from those on line 31.

Line 36 gives the number of horses-power developed in the steam cylinder by the expanding steam after the closing of the cut-off valve, calculated for the pressure on line 23.

Economic Results.—Line 37 gives the cost of the indicated horse-power developed by the steam cylinder, in pounds of feed-water consumed per hour. For experiments *A* and *C*, these quantities are the quotients of the division of the quantities on line 10 by those on line 34. For experiments *B* and *D*, these quantities are the quotients of the division of the quantities on line 10 by those on line 30.

Line 38 gives the cost of the total horse-power developed by the steam cylinder, in pounds of feed-water consumed per hour. For experiments *A* and *C*, these quantities are the quotients of the division of the quantities on line 10 by those on line 35. For experiments *B* and *D*, these quantities are the quotients of the division of the quantities on line 10 by those on line 31.

The total horses-power represent the entire work done by the steam. They include the indicated horses-power and the horses-power required to push out of the steam cylinder the back pressure against its piston; consequently, the total horse-power is the proper unit whose cost in heat, represented by the weight of feed water consumed per hour, is to be used as the correct economic result for comparison in cases like those of the present experiments.

Weight of Steam accounted for by the Indicator.—The weight of steam accounted for by the indicator, is the sum of the weight of steam present as such in the cylinder at any given point of the stroke of its piston, and of the weight of steam which had been condensed to furnish the heat transmuted into the power developed by the expanding steam at that point, calculated for the horses-power developed between the closing of the cut-off valve and the point in question, according to the indicator. If the point taken in the stroke of the piston is previous to, or at the point of cut-off, then there is no such condensation of the steam to be calculated, and the weight determined by the pressure shown by the indicator is all there is to be considered.

Line 39 gives the number of pounds of steam present in the steam cylinder at the point of cutting off during the experiments, calculated from the pressure on line 18. As the clearance and steam passage at one end of the cylinder were filled by the compressed back pressure due to the cushioning, these spaces are not included in the calculation.

Line 40 gives the number of pounds of steam present in the steam cylinder at the end of the stroke of its piston during the experiments, calculated from the pressure on line 19. For the reason just stated, the spaces in the clearance and steam passage are not included.

Line 41 gives the weight of steam condensed during the experiments, in the cylinder to furnish the heat transmuted into the

horses-power (line 36) developed by the expanding steam between the point of cutting off and the end of the stroke of the piston. In making this calculation, the dynamical value of one Fahrenheit unit of heat is taken at 789¼ foot-pounds, which makes the thermal equivalent of one horse-power $\left(\frac{33{,}000}{789\frac{1}{4}} = \right)$ 41·811847 Fahrenheit units; consequently, the number of horses-power on line 36 multiplied by 41·811847, and by the duration of the experiment in minutes, and the product divided by the latent heat due to the pressure on line 23, gives the quantities on line 41.

On line 42 is the sum of the quantities on lines 40 and 41, this sum being the number of pounds of steam accounted for during the experiments, by the indicator at the end of the stroke of the steam piston.

It will be observed that the weight of steam in the cylinder during experiments *A* and *C*, in which steam and air were used together, cannot be determined by the indicator, because the respective bulks of those substances present at the point of cutting off, and at the end of the stroke of the piston, cannot be known.

Difference between the Weight of Water Vaporized in the Boiler and the Weight of Steam accounted for by the Indicator.—Line 43 gives the difference between the quantities on line 4 and on line 39, and shows the number of pounds of steam condensed in the cylinder, during the experiments, by the interaction of its metal, at the point of cutting off.

Line 44 shows the per centum which the quantities on line 43 are of the quantities on line 4.

Line 45 gives the difference between the quantities on line 4 and on line 42, and shows the number of pounds of steam condensed in the cylinder during the experiments by the interaction of its metal, at the end of the stroke of its piston.

Line 46 shows the per centum which the quantities on line 45 are of the quantities on line 4.

An examination of the economic results (line 38) given in the case of the two comparable experiments *A* and *B*, shows that the total horse-power developed by the engine was obtained for exactly the same weight of feed-water consumed per hour, whether steam was used alone or in combination with air.

A similar examination in the case of the two comparable experiments *C* and *D*, shows precisely the same result.

Hence, *under the conditions of the experiments*, there was neither gain nor loss in economy of fuel due to the use of combined air and steam, comparably with the use of steam alone.

The question: On what grounds could any other result be expected? may be anticipated here and a reply given.

In the working of surface condensing engines, particularly of those in which steam of very low pressure was used with a high measure of expansion and an excellent vacuum (from twenty-six and one-half to twenty-seven and one-half inches of mercury), the observation has been made that oftentimes the condensation of the steam in the cylinder was so great as to produce a slapping noise whenever the piston came to the end of its stroke, and that the cylinder relief valves in this case had to be in constant use for the discharge of this water of condensation; but when enough air was allowed to leak into the condenser to reduce the vacuum to twenty-three or twenty-four inches of mercury, this cylinder condensation was so much decreased that the slapping noise ceased and the relief valves needed not to be used.

When the engine has a *closed* hot well or air pump reservoir, most of the air discharged from the condenser by the air pump is, instead of being thrown into the atmosphere, forced by the feed pump into the boiler, together with the feed water, the vacuum being thereby proportionally reduced, as this air returns to the condenser increased by whatever more may have leaked in at the various vacuum joints of the engine. Of course, after the air had accumulated in the reservoir beyond the capacity of the feed pump to draw off below the atmospheric pressure, the automatic discharge valve of the reservoir opened and delivered the air into the atmosphere, after which the discharge valve closed, and the same cycle was repeated.

Most feed-pumps are fitted with air-chambers to cushion the water discharge upon the contained air, thereby relieving the mechanism from shock and unnecessary strain, and producing a continuous flow to the boiler notwithstanding the intermitting action of the pump. Now, if a cock be placed on the top of the air chamber, it will, when left open, discharge continuously a considerable quantity of air, producing a corresponding improvement of the vacuum over what the latter was with the cock closed. Of course, the opening of the cock must be so graduated that only

the air will be discharged—no water—which is easily effected after a few trials. The squealing of the escaping air is a nuisance, but there is no other objection to the method. Cases have been known in which the vacuum has been thus improved several inches of mercury, but always with increased cylinder condensation, as evidenced by the production of the slapping noise in the cylinder caused by the increase of the water of condensation, due to the less air in the steam. In some cases, no increase in the economy of fuel followed the improved vacuum—the engine doing the same work—the loss by the greater cylinder condensation equalling the gain by the better vacuum, the temperature of the feed water remaining constant.

Steam, when intimately mixed with air, will not liquefy at the temperature that will condense it when unmixed. That the condensation of steam is greatly lessened by the admixture of air with it, is shown upon a large scale in the atmosphere which holds aqueous vapor in the state of gas at temperatures enormously below the liquefaction point of the vapor when not mixed with air, the vapor in such cases being superheated, and the greater the proportion of air, the less condensable is the vapor, other things equal.

The only direct experiments upon the influence of air mixed with steam in preventing the condensation of the latter upon metallic surfaces colder than itself, are those made in 1873, by Professor Osborne Reynolds, M. A., Fellow of Queen's College, Cambridge, England, a *résumé* of which was published in the *London, Edinburgh and Dublin Philosophical Magazine*, for 1874, which *résumé* is as follows, except that the description of the apparatus used and of the mode of experimenting with it are omitted:

"The object of this investigation is to ascertain how far the presence of a small quantity of air affects the power of a cold surface to condense steam. *A priori*, it seemed probable that it might retard condensation very much; for when pure steam comes up to a cold surface and is condensed, it leaves an empty space, which is immediately filled with fresh steam; so that the passage of the steam up to the cold surface is unobstructed, and if the surface could carry off the heat fast enough, then the rate of condensation would be unlimited. If, however, the steam is mixed with

air, then, as the mixture comes into contact with the cold surface, the steam will be condensed and the air will be left between the fresh steam and the cold surface; so that after condensation has commenced that surface will be protected by a stratum of air, and fresh steam will have either to displace this or pass through it before it in turn can be condensed.

"This question, besides its philosophical interest, has important practical bearings on the steam engine.

"(1.) If the quantity of air mixed with the steam affects the rate at which it condenses, then the ratio which the pressure of air bears to the pressure of steam in a condenser will materially affect its efficiency; this is particularly important with reference to the *surface condenser*.

"(2.) If air prevents [retards] the condensation of steam, then by sending air into the boiler of a *high pressure engine* [non-condensing engine] the condensation at the surface of the cylinder will be prevented [lessened] which, if allowed to occur, becomes a source of great waste; for when the steam comes into a cold cylinder it condenses, heating the cylinder and leaving water, which will again be evaporated as soon as the steam escapes; and this, in evaporating, will cool the cylinder. By preventing this, the mixing of air with the steam would effect the same object as the steam-jacket, only in a more efficient manner; for the heat communicated to the steam in the cylinder from the jacket, is not nearly so effective as that which is communicated from the boiler, in consequence of the steam in the cylinder being at a lower temperature than in the boiler.

"In making these experiments two objects were particularly kept in view.

"(1.) To ascertain if there is a great difference in the rate of condensation of pure steam and a mixture of steam and air—to ascertain in fact whether pure steam condenses at an unlimited speed.

"(2.) To ascertain if (and according to what law) the effect of air on the condensation increases as the proportion of air to steam increases.

"Of these two undertakings the first is the most difficult. The rate of condensation of pure steam is so great that it is practically impossible to measure it; and to institute a comparison between this and the condensation of a mixture of steam and air is like

comparing the infinite with the finite. It is practically impossible to keep any surface cold when an unlimited supply of pure steam is condensed upon it, so that under such circumstances the quantity of pure steam condensed is limited by the power of the surface to carry off the heat."

* * * * * * * * * * * *

"*Conclusions.*—The conclusions to be drawn from these experiments are as follows:

"(1.) That a small quantity of air in steam does very much retard its condensation upon a cold surface; that, in fact, there is no limit to the rate at which pure steam will condense but the power of the surface to carry off the heat.

"(2.) That the rate of condensation diminishes rapidly and nearly uniformly as the pressure of air increases from two to ten per centum that of the steam, and then less and less rapidly until thirty per centum is reached, after which the rate of condensation remains nearly constant.

"(3.) That in consequence of this effect of air the necessary size of a surface condenser for a steam engine increases very rapidly with the quantity of air allowed to be present within it.

"(4.) That by mixing air with the steam before it is used, the condensation at the surface of a cylinder may be greatly diminished, and consequently the efficiency of the engine increased.

"(5.) That the maximum effect, or nearly so, will be obtained when the pressure of the air is one-tenth that of the steam, or when about two cubic feet of air at the pressure of the atmosphere and the temperature 60° F. are mixed with each pound of steam.

"*Remarks.*—As the investigation was nearly completed, my attention was called to a statement by Sir W. Armstrong, to the effect that Mr. Siemens had suggested as an explanation of the otherwise anomalous advantage of forcing air into the boiler of a steam engine, that the air may prevent, in a great measure, the condensation at the surface of the cylinder. It would thus seem that Mr. Siemens has already suggested the probability of the fact which is proved in this investigation. I am not aware, however, that any previous experiments have been made on the subject, and therefore I offer these results as independent testimony of the correctness of Mr. Siemens's views as well as of my own."

The most potent cause of the lessened condensation of steam when mixed with air, is the separation of the molecules of the former by the molecules of the latter; for, evidently, there can be no condensation unless the steam molecules can coalesce; and, further, the steam when thus mixed with air is in the superheated state; that is, it has a temperature higher than is normal to its pressure as saturated steam, and as that excess of temperature must be removed before liquefaction can commence, the rate of condensation must be proportionally lessened.

When air is forced into a boiler or valve chest of a steam engine against a pressure greater than that of the atmosphere, it enters with the heat of compression, the temperature due to which may be greater than the temperature of the steam therein, and this higher temperature becomes a source of still greater superheating of the steam.

Professor Reynolds makes no allusion to these causes, and ascribes the entire retardation of condensation due to the air admixture, to the air preventing the steam from gaining access to the surface, blocking it out from reaching the surface so to speak. The final effect in the present case, as in all physical phenomena, is doubtless due to several causes, the one cited by the Professor being probably the least.

The surfaces of a cylinder or condenser when in use, are always covered with a stratum of more or less tenuity of water of condensation which, in its turn, is always covered with a stratum of more or less tenuity of air, and it is upon this air coating that any new discharge of steam will be delivered and not directly upon the metallic surfaces. The condensing power of these surfaces must be exercised upon the steam across both strata of water and air. If the Professor's reasoning were correct as to the retardation of condensation by the air molecules excluding the steam molecules from contact with the metallic surfaces by interposition, there should be no condensation at all, for the latter certainly never come in direct contact with them.

The use of air in connection with steam will not produce any economic effect, unless the two are *intimately* mixed; merely delivering them in masses together avails nothing. They must not only be mixed but *thoroughly* mixed, the molecules of the one must be placed between the molecules of the other, and there is, of

course, great difficulty in producing any such interposition. Time for what may be called natural mixing is utterly wanting during the operation of a steam engine, and if the mixture is to have its full effect in this case, some artificial means will have to be devised to produce it.

In the experiment with Mr. Strange's apparatus, the steam and the air were delivered into the cylinder in distinct masses, separately and successively. There was no time for natural mixing, and no provision had been made for artificial mixing by means of appropriate mechanism, consequently, no saving of fuel was produced; but this want of economic effect was not due to any unsoundness or error in the principle or theory, but solely to the fact that the principle was not applied under the conditions requisite for success. And herein will be found the explanation of many similar failures in which the practical results were a most disappointing outcome from unquestionably sound premises, the premises had not been realized and the failure was in that fact and not in them.

The difficulties in the way of practically realizing the idea of using a mixture of steam and air in a steam engine, are very considerable, not only must some artificial means of producing the proper mixing be devised, but the temperature due to the heat of the air compression in the compressor must be kept below the point at which the metals of the compressor will not work. A water-jacket around the compressor would doubtless accomplish this, but such an expedient involves pumps, extra water supply, pipes, etc., all of which are extremely objectionable as well as costly, and only to be resorted to when the gain is very considerable.

Some thirty or forty years ago, a Mr. Storms produced what he called "the Cloud engine," which was a non-condensing steam engine operated by a mixture of air and steam. In this case the air pump or compressor delivered the air at large into the steam room of the boiler, depending upon the conditions existing therein to effect the proper mixing. An experiment was made with this system on a very small steam cylinder at the "Novelty Iron Works," New York City, the power in the two cases of using first the mixture and then the steam alone being measured by a friction brake. The writer has no knowledge of the details of the

apparatus, nor of the experiment which was said to have been satisfactory in showing a very large economy in favor of the mixture. Chief Engineers Zeller and Hunt would have repeated this experiment by means of Mr. Strange's apparatus, delivering the compressed air from the compressor into the steam room of the boiler instead of into the valve-chest of the cylinder, had they not been prevented by a decision of the Navy Department not to allow the least expenditure of money for experimental purposes in steam engineering, the cost of making Mr. Strange's apparatus and experimenting with it having been entirely defrayed by that gentleman.

In the case of all steam engines, there is a very considerable though unintentional mixture of air with the steam. The feed pumps force air as well as water into the boilers, but in unknown proportions. This air, on arriving in the boiler, is immediately disengaged from the water, rises into the steam room, and passes with the steam in a more or less mixed condition to the cylinder, and thence to the condenser, lessening, without doubt, the condensation of steam in the first, due to the interaction of its metal, and in the latter by the presence of the mixed air, with the result that less fuel is required to produce a given engine-power as measured in the cylinder by an indicator (not by a friction brake), and more of this power is required to work the feed pumps and to pump out the air from the condenser, the vacuum in the latter and the temperature of the feed water being maintained constant in both cases. Also, a larger condenser and air pump would be required to produce the same condensation and vacuum; but a smaller boiler would supply the steam for the given power, the rate of combustion of the same fuel remaining the same. It is something, however, for engineers to know that the inleakage of air is not so entirely detrimental as is usually supposed, and that it has some compensations for its obvious disadvantages.

Supposing, now, that a method of perfectly mixing the air and steam were devised, then, as the beneficial effects of using this mixture consist entirely in the lessened cylinder condensation due to the interaction of its metal, the benefit would be diminished exactly in the proportion that cylinder condensation is diminished by other causes. Thus, other things equal, the larger the cylinder, the thinner its metal; the nearer the proportion of its diameter to its

length for producing the minimum surface with a given space displacement of piston per stroke, the less surface in the steam passages; the application of a steam jacket to the cylinder, the lower the initial pressure of the steam and the higher the back pressure against the piston, the smaller the measure of expansion with which the steam is used, the more the steam is superheated; the greater the reciprocating speed of the piston, etc., etc., the less will be the economic effect obtained from the admixture of air.

That the intermixing of air with steam would prevent the condensation of the latter, is by no means a recent discovery; it was very early known in the use of steam for mechanical purposes, having been practiced certainly not later than 1766 in Savery's apparatus, as improved by Desagulier and others for raising water by means of the vacuum formed by the condensation of steam; and it also constituted a feature of Newcomen's atmospheric engine about 1772, after the latter had been perfected by the celebrated Smeaton. Farey describing this engine, in 1827, says:

"It was found advantageous to admit a continual leakage of air into the cylinder; for this purpose a small cock was inserted into the bottom of the cylinder, and was opened as much as it could be to allow the piston to complete its working stroke. When this cock was shut, the engine required a greater counterweight to return the piston, or else it would move slower in the returning stroke, so that in either case the power of the engine was lessened, when it worked without this leakage of air; and the effect of a given quantity of fuel was lessened by shutting the air-cock, in the proportion of twelve to eleven, and in other cases as twelve to ten.

"The air thus admitted into the cylinder, would have a beneficial effect to diminish the condensation of the steam against the internal surface of the cylinder, because the air would have a tendency to collect against that surface, and form a non-conducting lining to the cylinder, so as to keep the steam from actual contact with it.

"As the advantage of admitting air into the cylinder is only to diminish condensation, it is evident that in those engines which condense the greatest proportion of steam, the advantage of air will be greatest."

The use of air mixed with steam in any considerable proportion is probably confined to non-vacuum engines; the number of these,

however, is very great and their consumption of fuel enormous. In view, then, of the possible economic value of the problem to the world, an early effort should be made to exhaustively solve it, for the importance of any method that will lessen—though ever so little—the cost of fuel for the great motor of civilization on which the progress of our race seems to depend, is so great that the expense of the solution appears comparably as nothing.

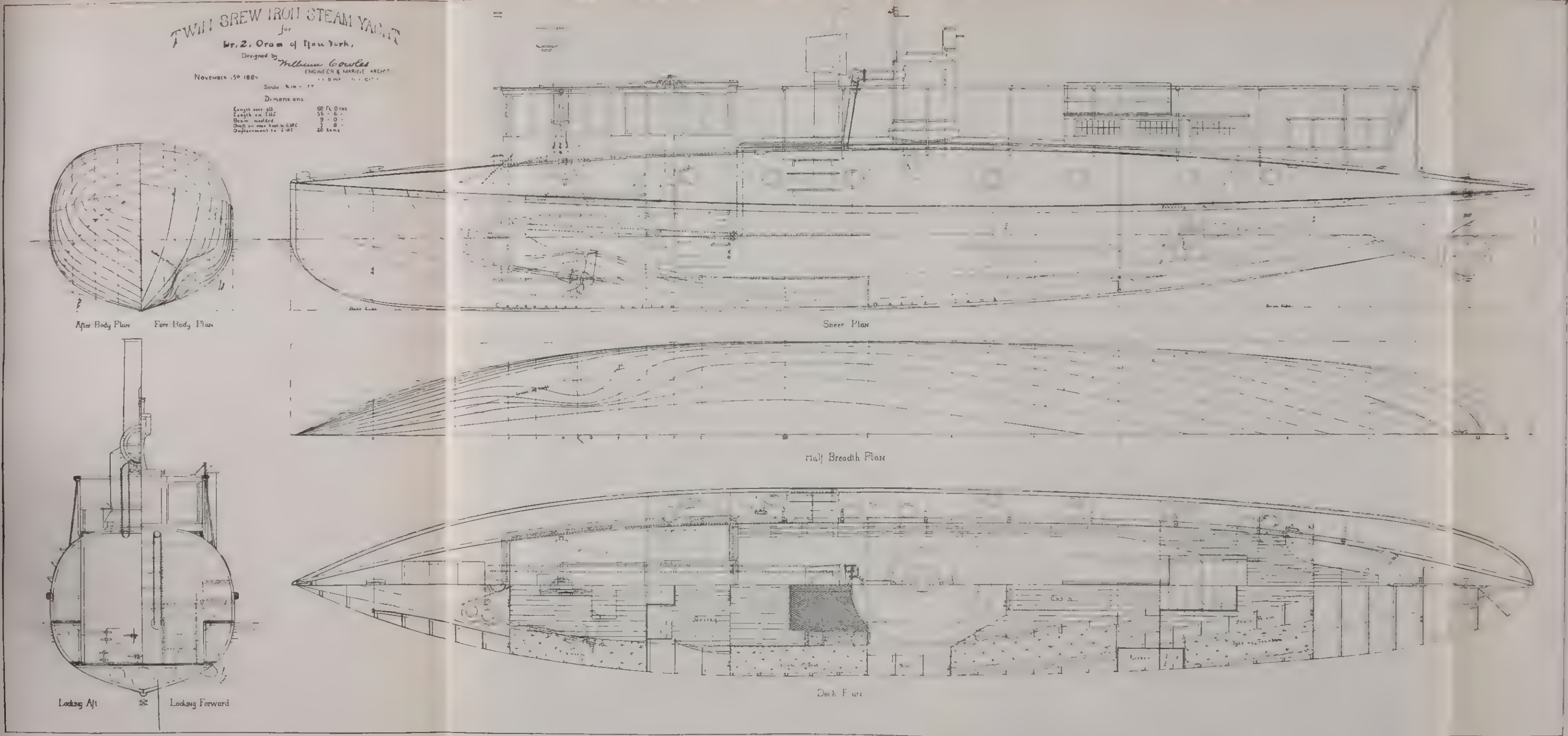
If an experiment be made with mixed air and steam, by delivering the compressed hot air into the steam room of a boiler, the air should be delivered first into perforated pipes arranged in gridiron form over the entire area of the steam room; and it should then emerge through the small holes of these pipes into the steam room, thereby obtaining a more intimate mixture with the steam in the short time available for that purpose, than if delivered into the steam room in bulk.

The subject is of sufficient importance and promise to warrant an exhaustive experimental investigation, and one of the objects of this paper is, by supplying the facts thus far obtained, to guide the future experiments by the shortest and surest path.

Quantity of Electrical Elementary Particles.—Herwig attempted to estimate the magnitude of electrical elementary particles, but he made some very arbitrary assumptions, and confounded the ideas of "mass" and "quantity" of particles. E. Budde proposes the questions: (1.) Are there in nature discrete elementary particles of electricity? (2.) What is their magnitude? According to the analogy of conclusions drawn for carbon, the questions may be answered as follows: If there are in nature discrete elementary particles of electricity, it is to be expected that an absolutely definite, very small quantity of electricity occurs, and plays an important part in a large number of processes. If experiment shows us such an amount, then that amount of electricity is the probable quantity of the particles of electricity. The region in which we must investigate, is that of those processes in which electricity interacts with ponderable atoms, and defines the action of those ponderable atoms; that is to say, the region of electrolytical decompositions and combinations. From considerations based upon Faraday's law, he deduces the value

$$E = 0{\cdot}00000051 \text{ mg.}^{\frac{1}{2}} \text{ mm.}^{\frac{3}{2}} \text{ sec.}^{-1}.$$

This value is the probable "Atomic Quantity of Electricity." It may be a multiple, but with the same probability with which $C = 12$, and not 6, or 3, is E the quantity of electrical elementary particles. For, even if electricity can be split into smaller parts than E, it is not clear why such a smaller part is never met with in experiment.—*Wied. Annalen, No. 8, 1885; P. Mag., Sept. 1885.*


TWIN SCREW IRON STEAM YACHT
for
Dr. Z. Oram of New York,
Designed by William Cowles
ENGINEER & MARINE ARCHT
November 5th 1884
Scale
Dimensions
Length over all 60 ft. 0 ins.
Length on L.W.L. 55 - 6 -
Beam moulded 9 - 0 -
Displacement to L.W.L. 20 tons
After Body Plan
Fore Body Plan
Sheer Plan
Half Breadth Plan
Looking Aft
Looking Forward
Deck Plan

THE ORAM SYSTEM OF MARINE PROPULSION.

The Oram System of Marine Propulsion is designed to procure higher speed in steamships with an increased carrying capacity, and to avoid some of the risks of accident incident to propulsion by stern screws.

It consists of an improved form and construction of hull, in which provision is made for a novel location and operation of screw propellers in cavities or recesses on both sides of the vessel.

The propellers are located about one-fifth of the length of the vessel aft of the bow. The cavities in which they are placed are so shaped as to guide the water to and from the propellers with the least possible friction or resistance, and at the same time avoid dangerous protrusion of the propellers beyond the hull.

The propellers are susceptible of rotating independently and are attached directly to the shafts of the engines, having angles of divergence, causing a downward, outward and rearward discharge of the water, attended with a corresponding reaction propelling the vessel.

The recesses are formed of curved surfaces, proportioned and arranged in relation to the propellers so as to guide by the forward curves the incoming water directly to the propellers. The after curves direct the disengaged water in diverging lines, relieving the pressure at the bow and greatly reducing the skin friction of the vessel.

The propellers are susceptible of running at higher speed, require shafts of less diameter than the larger stern screws, and are so short as to be really the engine shafts themselves.

A saving of weight and cost is the immediate result of this form of construction, which not only occurs in the propellers and shafts, but in the engines themselves, which being higher speeded, are of much less weight for the same piston displacement and power.

The long shaft of great weight and the alley to contain and protect it are avoided, and the transverse bulk-heads are unimpaired, thus promoting safety, and the space is available for useful and remunerative storage.

The necessity for longitudinal stiffness in the hull, to sustain

the bearings of the long shaft in proper alignment, does not exist, and the danger from flexure and straining of the hull disabling the shaft and propeller is avoided, so that a degree of elasticity and flexibility of hull construction becomes admissible, which in stern-screw propelled vessels could not be tolerated.

In the event of collision bending or straining the hull the increased security of the machinery against interruption of running is important and valuable, and under some conditions may save the vessel from total loss.

The facility afforded by leaving the hold clear of machinery, to place the cargo or stores of the vessel in compartments separated by bulkheads, is obvious, and for purposes of warfare is important, as permitting constructions not practicable where the shaft alley and shaft divide the lower hold through nearly its entire available length.

The shafts and all of their bearings are constantly under inspection of the engineers on duty, and from their lightness and short length are not so liable to accident as shafts of great weight and length, and couplings being unnecessary accidents thereto are avoided. The danger of racing and breaking, consequent therefrom, is avoided by the location of the propellers.

Economy of fuel in running, of space required for machinery, and in first cost of construction, together with augmented speed and immunity from accident, are claimed for this system.

The accompanying illustration shows a yacht of sixty feet in length, now in course of construction, embodying this invention.

Plans of such a vessel have been submitted to the U. S. Naval Board, having in charge building of the new cruisers authorized by Congress, and are now under consideration by them.

S. L. W.

Philadelphia, April 15, 1886.

DISTRIBUTION OF EARTHY MATTER IN PLANTS.—Berthelot and André have published their second, third and fourth memoirs on the general march of vegetation in an annual plant. They find that the mineral matters which become insoluble by incineration have a marked tendency to accumulate in the leaves. In plants with a languishing vegetation, however, they sometimes seem to be arrested in the roots, probably in consequence of the insufficient action of the agents which render them soluble, and enable them thus to reach the leaves through the circulation of the sap.—*Ann. de Chim. et de Phys., Aug., 1885.*

SOUTH STREET BRIDGE.—NEW WEST APPROACH.

By G. Whitefield Chance.

The South Street Bridge, crossing the Schuylkill at Philadelphia, is one of the few bridges in this country erected on large cylindrical iron columns, filled with masonry, as piers. Two other bridges with such piers are well known, viz., that across the Harlem River, and the great Atchafalaya Bridge, on the Texas and Pacific Railway, built by Major Anderson.

It is very doubtful whether this method of obtaining supports for trusses possesses any material advantage over the ordinary caisson and masonry pier method; while for arch abutments, where the horizontal thrust comes into play so powerfully, this style of pier, as at present built, is of course not advisable.

The bridge, which it is our purpose to describe, was built between the years 1872 and 1876 under a commission authorized by an act of the State Legislature. It was erected in opposition to the wishes of City Councils, who filed a protest against the action of the Legislature.

Moses A. Dropsie and ex-Judge Findlay were the successive Presidents of the Bridge Commission. A contract to build the structure was made by the Commission with John W. Murphy, C. E., on March 30, 1870, for $770,000. The total cost amounted to $865,000.

Mr. Murphy died about a year before the completion of the bridge, and it was finished by his executors.*

The somewhat great length of time consumed in the erection of the structure was mainly due to legal delays.

GENERAL DESCRIPTION.

The bridge and approaches have a total length of 1,934 feet 7 inches. The bridge proper consists of two 195 feet 8 inch fixed spans, of the Murphy-Whipple form of truss, and a draw 198 feet 2 inches long, of the same type between.

The depth of all the trusses is twenty-seven feet.

---

*See biographical notice of John W. Murphy, C. E., by W. Barnet Le Van, read before the FRANKLIN INSTITUTE, Philadelphia, October 21, 1874.

The shore spans have a breadth of thirty-six feet between trusses, while the total width between railings on the outside of footways is fifty-five feet.

The columns of the trusses are of the Reeves patent.

The shore ends of the fixed spans each rest on stone abutments, while the river ends each rest on two eight feet in diameter iron columns. These columns are braced laterally, and the space between them filled in with loose stone and masonry.

The columns are of cast iron, and are in sections 10 feet in length, 1¾ inches thick, bolted together by inside flanges at each end, 2¾ inches wide and 1¾ inches thick. The flanges are pierced with holes five inches apart from centre to centre, which are filled with one and one-fourth inch bolts. The sections resting on rock are cut-off square and secured to the rock by means of iron brackets and fox wedges. Each ten feet section weighs 14,600 pounds. The inside of the columns is filled with rubble masonry.*

PIVOT PIER.

The pivot pier is formed of eight columns, four feet in diameter spaced equally around a circle of twenty-eight feet diameter, and tangent thereto. These columns carry the track on which the wheels of the turn-table run. The pivot rests on a six foot in diameter column, and has a Sellers' Patent Centre.

The six foot column weighs 10,800 pounds per section of ten feet, and the four foot column, which is one and one-fourth inches thick, 6,800 pounds per ten foot section.

The columns average about sixty feet in length. They are all braced vertically and horizontally by **I**-beams and tie rods, and below low water they are surrounded by a cribwork filled with rip rap. The load on the pivot pier from the draw span when open, is 400 tons.

The clear water way on each side of the pivot pier is seventy-seven feet.

Piers of masonry are placed up and down stream eighty-eight feet from the centre of pivot pier for supporting the draw when open, and also to serve as guard piers.

---

* For full description of method of sinking cylinders, see article by D. McN. Stauffer JOUR. FRANKLIN INSTITUTE, Vol, 64, p. 320.

EAST APPROACH.

Commencing at the river and going east is the abutment pier, 40 feet 10 inches in length, built on a hard gravelly soil; it is of granite with pilasters and Doric capitals.

Then come three conoidal brick arches of original design built on a line which curves to the left. The curve has a radius of 160 feet, and the central angle subtending the arc between the tangents at beginning and end of curve is 33° 25′, the length of curve being 114 feet 6 inches. The facing of these arches is of brown sandstone with granite trimmings, the piers being granite.*

After the arches, there is 363 feet 6 inches of broken range ashlar retaining wall of brown sandstone with granite trimmings, the approach descending at a steep grade to the level of the street. The total length of the approach is 518 feet 10 inches.

OLD WEST APPROACH.

Commencing at the river and going west was an abutment 40 feet 10 inches in length, similar to the eastern abutment, placed on 517 piles driven butt down, and connected by a timber grillage. Then came nine segmental brick arches, each of 43 feet 6 inches span, and 14 feet rise, 2 feet deep, placed on granite piers 5 feet 6 inches wide. These arches covered a distance of 391 feet 3 inches. After the line of arches was an abutment pier of granite 62 feet 4 inches long. Between this pier and the granite retaining wall 87 feet 4 inches long ending the approach, were three Pratt trusses, 244 feet 9 inches total length, resting on eight wrought iron columns. These trusses carried the approach across the Philadelphia, Wilmington and Baltimore and the tracks of the West Chester Railroad.

In the new west approach, the above enumerated features remain intact with the exception of the line of arches with their piers and the railroad abutment pier.

The total length of the west approach is 826 feet 6 inches.

PROFILE.

The general character of the soil along a profile section through the centre line of the bridge, is as follows: At the surface, tough

* For full description of conoidal arches, see "Proceedings of Engineers' Club of Philadelphia," Vol. I, p. 95.

mud extending to considerable depth in some places, then coarse gravel underlying, then very coarse gravel, and finally an undulating micaceous gneiss. Lying directly on the rock in the river bed, are considerable quantities of drift wood, evincing great age and a long occupation by the river of its present position.

The rock which at the eastern river abutment is five feet below the bed of the river, or seven feet below low water, shelves off to eighteen feet at the draw pier, or thirty-four feet below low water, while at the western column pier it is thirty feet below the bottom or thirty-eight feet below low water.

The iron columns were all sunk to rock by means of the plenum pneumatic process.

CRACKS IN COLUMNS.

Some of the iron columns of the pivot pier have cracked badly.

Some of these cracks occurred shortly after the bridge was erected.

The columns were cast from Government cannon, originally made from cold blast charcoal pig.

The cracks commence at the joints and extend both ways in some instances, generally vertically, as far as six feet from the joints. They vary in width from zero to two and one-half inches.

It is most likely that the cracks were caused by water freezing inside of the columns. The force exerted by water in freezing, or in its effort to freeze when confined, is probably as great as 30,000 pounds per square inch. (Trautwine.)

From the fundamental formula in hydromechanics,

$$e = \frac{r p}{T}$$

in which,

$e =$ the thickness of a pipe to resist longitudinal rupture,
$p =$ the pressure on unit area,
$T =$ ultimate tensile strength of material of pipe,
$r =$ internal radius of pipe,

we may calculate how thick a pipe or column would be required to sustain a pressure of 30,000 pounds per square inch. Taking the ultimate tensile strength of the metal of Government cannon at 38,000 pounds per square inch, we find that the column should have a thickness of about eighteen inches, while it has only one

and one-fourth inches. This theoretical thickness is probably too great, owing to the fact that expansion could take place and so relieve the pressure.

Water could have entered the columns in several ways, either

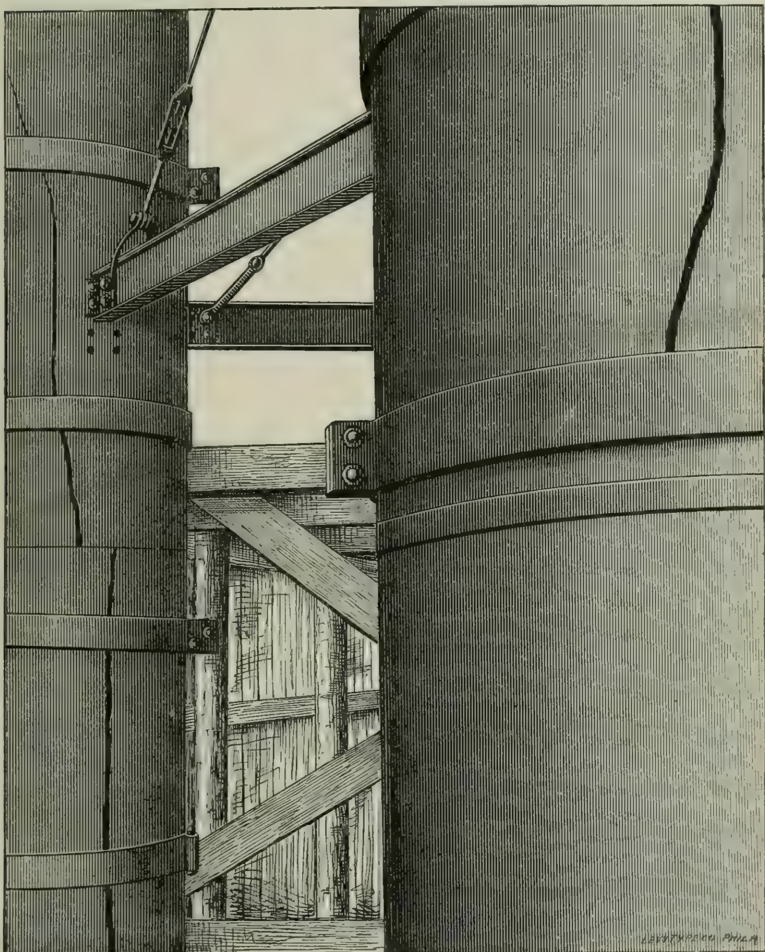


PLATE I. Exhibiting Cracks in Iron Columns.

at the section joints, from the top, or through holes in the columns, four of which are shown under the **I**-beam in the column on the left of *Plate I*, which is an engraving taken from a photograph by Prof. L. M. Haupt. A somewhat significant fact is that out of nine

large cracks in the pivot pier columns, six are below the level of high stages of the river.

The verticality of the cracks shows a horizontal force of some kind acting radially from within.

The cracked sections have been bound around by wrought iron bands $\frac{3}{4}$ of an inch thick by $5\frac{7}{8}$ inches wide, clamped with bolts and nuts.

OLD ARCH PIERS.

The arch piers of the western approach were each built on eighty-four piles, not driven to rock, but to a hard gravel stratum. These piles, together with the piles used under the abutment piers, some 1,200 in all, were of Nova Scotia spruce, averaging ten inches on the head, and were driven butt ends down.

FAILURE OF.

On Sunday, February 10, 1878, a very unfortunate accident occurred to the west approach.

Pier No. 7, numbering from the river abutment westward and 385 feet from the river, sank at its northern end some sixteen feet, involving a falling in of its two arches; and since the arch piers were not sufficiently massive to withstand the horizontal thrust of each arch separately without the resisting thrust of the adjoining arch, the whole line of arches fell in ruins.

At pier No. 7, the piles were driven through fifteen feet of mud to a bed of gravel, by a 2,000-pound hammer, and received, as a final test, four blows from the hammer falling thirty feet, when one inch downward motion was the maximum allowance for each blow.

At the large abutment pier, 100 feet west of the failing pier, the gravel bed just mentioned is within a foot of the surface, and it seems to dip from this point uniformly towards the river, where it is forty-five feet below the surface.

D. McN. Stauffer, Assistant Engineer of the bridge, says: "The estimated load on the piles under the pier was 2,000 tons, or twenty-three tons on each pile. According to Rankine, for pile work under similar circumstances, each pile was good for eight tons frictional value, leaving fifteen tons on the toe of the pile. The tremor produced in the piles by travel on the bridge would gradually loosen them sufficiently to allow percolation of water down their sides, and finally throw the whole weight on the toe of

Plate Girder Approach to ~ SOUTH STREET BRIDGE. ~

PLATE III

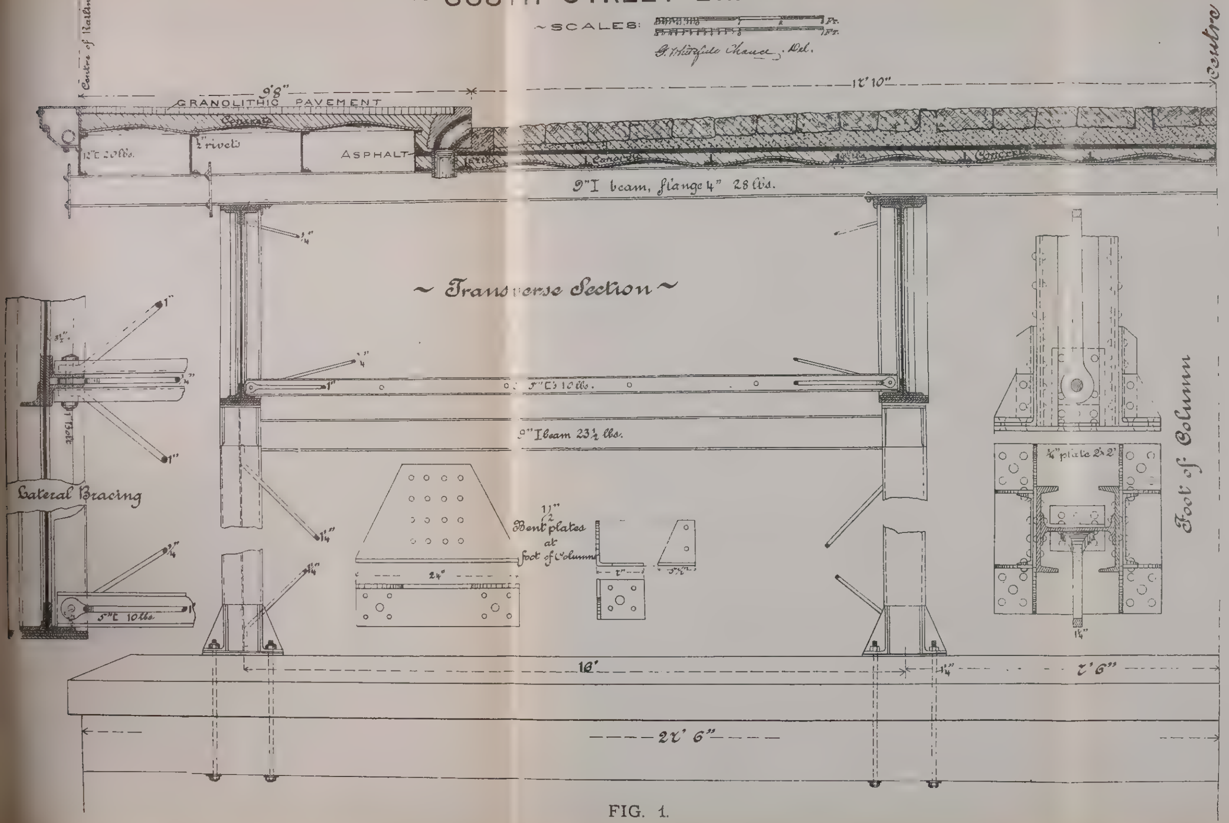


FIG. 1.

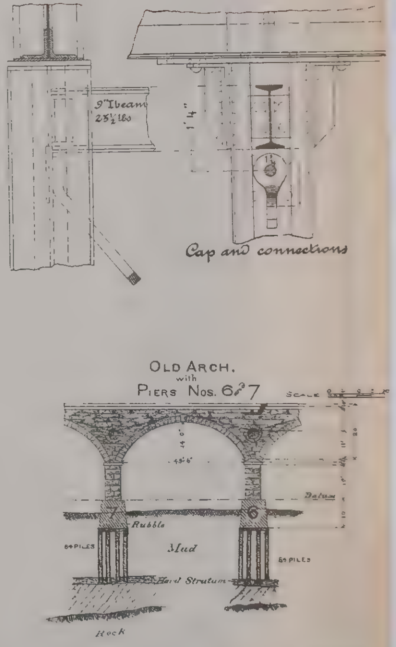


FIG. 2.

the pile. If the bed of gravel was merely a thin bed, or pocket, as the water softened it the additional weight, before sustained by friction, probably allowed a bunch of piles at the north end of the pier to settle down into the soft material beneath the gravel." He also says:

A small expenditure to put in tie rods between the two adjacent piers to No. 7 would have saved seven out of the nine arches. Borings made twenty feet from each end of the failing pier showed, at the south end gneiss 33 feet 8 inches below the surface, overlaid by from eighteen inches to twenty inches of gravel and then a considerable thickness of a hard, very compact, yellowish clay.

At the north end, rock was found thirty-seven feet below the surface, above which was 3 feet 8 inches of black mud and above this seven feet of gravel mixed with clay.

In excavating for the new foundations of pier No. 7, the largest pile found was fifteen feet in length. Some of the piles of the east row were found to have their ground ends higher than their heads, the piles pointing in a northeasterly direction (the pier runs nearly North and South), making an angle of about 30° with the horizon. The piles of the row next to the east row were found to have been broken off two feet below their heads, the remainder being held in place by the concrete surrounding.

The diagram of old arch with piers Nos. 6 and 7 (*Plate III. Fig. 2.*) will render it easy to make calculations for the total load on each pile.

The cut stone masonry of the face of the arch, including the arch rings, spandrel walls and coping, extended in on an average three feet. The arch was of brick while the haunching, as shown by the dotted lines, was of rubble. Above the haunching was gravel filling, on top of which was a granite pavement four inches deep. The piers were of granite, while the foundations were of rubble. A timber grillage, some two feet thick, covered the piles. The barrel of the arch was fifty-five feet long.

From Trautwine's formula for safe load for piles, we have:

$$L = \frac{F \times \cdot 023 \sqrt[3]{h} \times w}{s + 1}$$

in which,

$L =$ safe load in tons;
$h =$ fall of ram in feet;
$w =$ weight of ram in pounds;
$s =$ last sinking of pile in inches;
$F =$ factor of safety.

Using the quantities before given, $h = 30$ feet : $w = 2{,}000$ pounds, and $s = 1$ inch, we find, taking one-third as the factor of safety, which is large considering the conditions there present, the safe load would equal 23·8 tons per pile.

NEW GIRDER APPROACH.

A temporary wooden structure was used for travel during the construction of the present handsome girder approach, completed December, 1885.

The new girder approach, which takes the place of the old arches, consists of 446 feet of wrought-iron plate girder bridge work, 57 feet in width, with a roadway 35 feet 8 inches, and two footways, each 9 feet 8 inches in width.

It is divided into nine spans, supported by wrought iron columns on masonry piers. Six of the piers are built on the old foundations, while the seventh or failing pier has an entirely new one. (*See Plate II.*)

The railroad abutment pier adjoining the arches was reduced in length to fifteen feet.

The foundations of pier No. 6 were strengthened at its south end and its plan was changed to make its transverse centre line oblique to the centre line of bridge, in order to accommodate certain railway tracks; this involved in all a driving of forty-six piles.

Pier No. 7 was built over again, and its plan was also changed so as to make it parallel with pier No. 6.

Eighty-eight new piles were used in its foundations, from 22 to 30 feet long and about 12 inches in diameter on the head, some of which were driven to rock by a 2,200 pound hammer. These piles were of oak, straight growth and barked, and were originally about forty feet long when driven, but were cut off to –9 feet below datum.*

* City datum, $8\frac{52}{100}$ feet above mean low water, Delaware R.

The spaces between these piles were filled for three feet below their heads with concrete. They were capped transversely to the line of bridge with 12 x 12 inches hemlock timbers, fastened to the piles with locust tree nails 1¼ x 24 inches, and a platform 10 x 60 feet of 10 x 12 inches hemlock timbers at right angles to the caps, laid close, was then secured to the cap pieces at crossings by 1¼ x 18 inches locust tree nails.

Rubble masonry 9 x 59 feet was then laid on the platform and carried up with a batter of about one foot on two-thirds inch all around to within –33·5 feet of curb on roadway. Five courses of pitched ashlar, each about two feet deep, were then laid on and covered with a coping eighteen inches thick. Each pier is 5 feet 6 inches wide, and has sixteen bolts and eight plates built into it for anchoring the iron columns; there are two plates and four bolts to each column.

PLATE GIRDER SPANS.

The plate girder spans are each about forty-nine feet in length, and are formed of four lines of girders each about four and three-fourths feet deep, resting on four wrought iron columns at each pier. Each column is formed of two twelve-inch channel bars, weighing thirty pounds per lineal foot, connected on the flange side of their webs by a ten and one-half inch **I**-beam, thirty pounds per lineal foot. The columns are bolted to the piers by four one and one-fourth inch wrought iron bolts, extending through the coping and two additional courses of stone, and connected by two tie plates, each 4 x ¼ x 24 inches.

The inside lines of columns are placed sixteen feet transversely on the piers from the outside lines, while the inside lines are fifteen feet apart. Each column of the outside lines is braced with each column of the inside lines, on each of the piers, by a nine-inch **I**-beam, twenty-three and one-half pounds per lineal foot, placed at the top of columns, and the panel formed by the two columns, **I**-beam and pier, is tied with two one and one-fourth inch square wrought iron rods, with turnbuckles, placed diagonally.

The outside and inside lines of girders are connected over each pier and half way between spans by vertical panels of bracing, each consisting of two five-inch, ten-pound channel bars, placed at the bottom of the webs of the girders, and two three-fourths inch round wrought iron rods, placed diagonally, and running

from the top of one girder to the bottom of the other, with connections, as shown in *Plate III. Fig. I.* Each horizontal panel formed by the two girders and the two five-inch channels, just mentioned, dividing the span into two equal parts, together with the two five-inch channels over each pier, is tied by two diagonal round wrought iron rods, each one inch in diameter. All transverse rod bracing is tied at intersections by copper wire.

There is no bracing of any kind connecting the inside lines of girders.

At every second pier a distance of about one-half inch is allowed between the ends of girders for expansion, and slotted holes are made to give the bolts proper play.

FLOOR FORMATION.

On the girders in each span are placed, transversely, eighteen wrought iron nine-inch I-beams, flange four inches, twenty-eight pounds per lineal foot. The middle and two end beams in each span are riveted to the girders. Riveted to the I-beams mentioned, longitudinally, on each side of the bridge, to form the footways, are four twelve-inch channels, twenty pounds per lineal foot, placed 2 feet 9 inches apart; on the top of each outside line of channels, is riveted an eight inch, twelve and one-half pound channel to retain the footway surfacing and concrete. To this channel and the one below, the cornice, formed of channels and angles weighing about sixty pounds per lineal foot, is riveted. On the ends of the floor I-beams, ornamented castings are affixed.

Upon the channels and I-beams of the floor formation, are placed buckled plates, riveted thereto on two edges with one-half-inch rivets. These plates are of wrought iron ¼ inch thick and 3 feet square with 2½ inch rise in the middle.

Upon the unsupported edges of the plates are placed tee bars, six and one-half pounds per lineal foot on roadway, and five and one-half pounds on footways. The flanges of these tees are riveted to the edges of adjoining plates.

At piers Nos. 1, 2, 4, 6 and 8, expansion joints are made in the floorway formation. Each is formed of two angles riveted to the upper flanges of two adjacent I-beams, and a plate, ⅜ inch thick by 15 inches wide, to which 2 x 2-inch angles are riveted, placed upon the upturned edges thereof, with the angles turned down.

Elevation of Girder Approach

—to—

SOUTH STREET BRIDGE.

Scale.

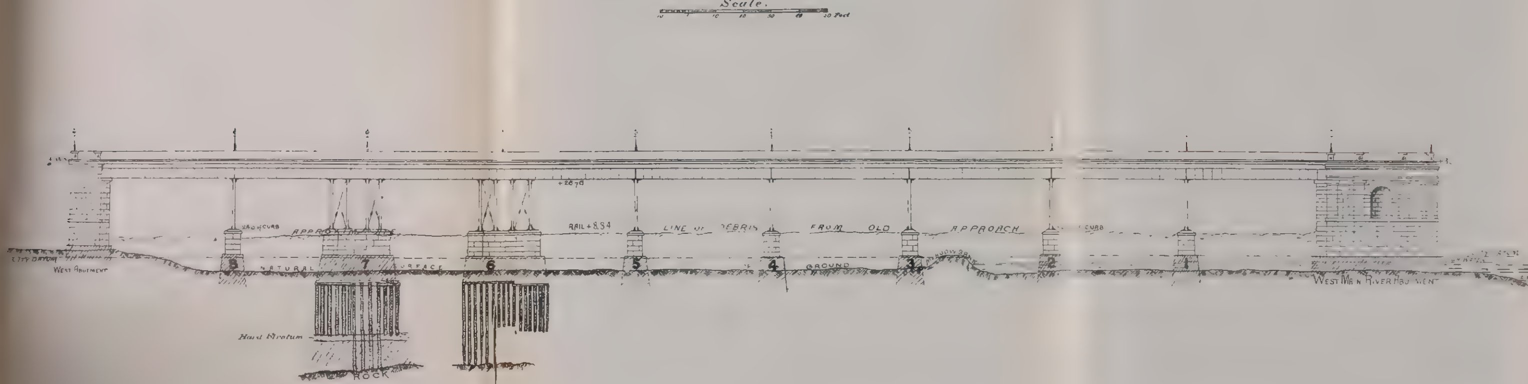


PLATE II.

SURFACING.

Upon the buckled plates, up to one inch over their apices, is placed a layer of concrete, formed of two parts of gravel and one of German Portland cement, upon this is a layer one inch thick of Neuchatel asphalt composition, ironed to make water tight joint —arranged as shown in *Plate III. Fig. I.* A layer of concrete, four and one-half inches deep in the middle of roadway, covers the asphalt. The concrete is of the usual formula, viz , stone, four parts ; sand, two parts ; cement, one part.

On this concrete, is a layer of the first mentioned concrete two inches deep (not shown in *Plate III*), in which the granite blocks of the surface covering are laid. These blocks are about 6 x 9 inches in breadth and length and 3 inches deep. No joints over three-fourths inch wide were allowed by the specifications. As soon as the top layer of cement mortar had set, the joints of the pavements were grouted with Portland cement and sand half and half. No travel was allowed for two weeks after grouting. No stones over one and one-half inches in their largest dimension were allowed in the concrete of the superstructure.

The footways are formed of a layer of concrete about two inches deep over the apices of the buckled plates, on which is laid two inches deep, "Stuart's Granolithic Pavement," forming a most excellent surface.

Over piers Nos. 1, 3, 5 and 7 are projecting lookout bays in the footway formation. Each span of superstructure weighs 400 tons.

SPECIFICATIONS

The specifications stipulated in regard to the work as follows :

* * * * * * * * * *

(49.) Portland cement must weigh 112 pounds per struck U. S. bushel of 2150·42 cubic inches. It must be ground so fine that no residue remains after passing through a wire cloth sieve 3,600 meshes per square inch.

After being made into a briquette and remaining seven days in water it must show a tensile strength of not less than 200 pounds per square inch.

Other cement must not leave more than fifteen per cent. residue on wire sieve (3,600 meshes per square inch), and exhibit a

tensile strength of seventy-two pounds per square inch after remaining in water seven days.

* * * * * * * * * *

(51.) All mortar is to consist of cement and sand in the proportions of one part cement, two parts sand.

* * * * * * * * * *

(54.) All wrought iron shall be uniform in quality, tough, fibrous, free from cracks and flaws and with perfect edges.

All wrought iron in tension shall be capable of withstanding a tensile stress of 46,000 pounds per square inch of full section of specimen, with fifteen per cent. (web plates five per cent.) extension in eight inches, and of supporting fifty per cent. of that weight without permanent set.

All lateral and transverse tie rods shall have adjustable sleeve nuts and connections equal to the strength of the rods.

(55.) In all rivet work, the holes shall be accurately spaced and punched truly opposite. The rivets shall be of the best quality of rivet iron; shall completely fill the holes and have hemispherical heads.

* * * * * * * * * *

(58.) All new iron work shall be cleaned and receive one coat of red oxide of iron ground in pure boiled linseed oil before leaving the shops, and after erection shall receive two coats of the same tinted dark brown or black, as directed; the pigments also being ground in oil.

The contract price paid by the city for the work was $81,920. The work included some repairs to the abutments and some other minor details necessary to place the approach in complete order for travel.

Work was commenced about the middle of June, 1884, and the approach was thrown open in the early part of December, 1885.

My acknowledgments are due to Mr. Samuel L. Smedley, Chief Engineer and Surveyor of Philadelphia; Mr. J. Milton Titlow, Principal Assistant Engineer, and Mr. Lindley M. Winston, Inspector, who kindly furnished me with many of the data embraced in this paper.

EXPERIMENTS ON THE TRANSMISSION OF POWER BY GEARING.—MADE BY MESSRS. WILLIAM SELLERS & CO.*

By Wilfred Lewis, Philadelphia, Pa.

[*A Paper read before the American Society of Mechanical Engineers, at the Boston Meeting, 1885.*]

The idea of determining, by experiment, the relative values of different forms of gearing, as measured by the economy with which they transmitted power, originated with Mr. J. Sellers Bancroft, in the spring of 1883, and soon after the following investigation was begun at his instance and carried out under his direction. The question implied was one of continual recurrence, upon which diverse opinions were found to exist, and these were so frequently based upon general impressions or loose observations, in which some important fact or condition was wanting, that the necessity was felt for more definite and reliable information as a guide in the construction of high-class machinery. To obtain this in such a manner as to leave no room for doubt, it was proposed that the gearing itself should be made to bear testimony, and the writer accordingly undertook to prepare the design for an apparatus which should thoroughly test the efficiency of the more common forms of gearing, namely, worm, spiral and spur.

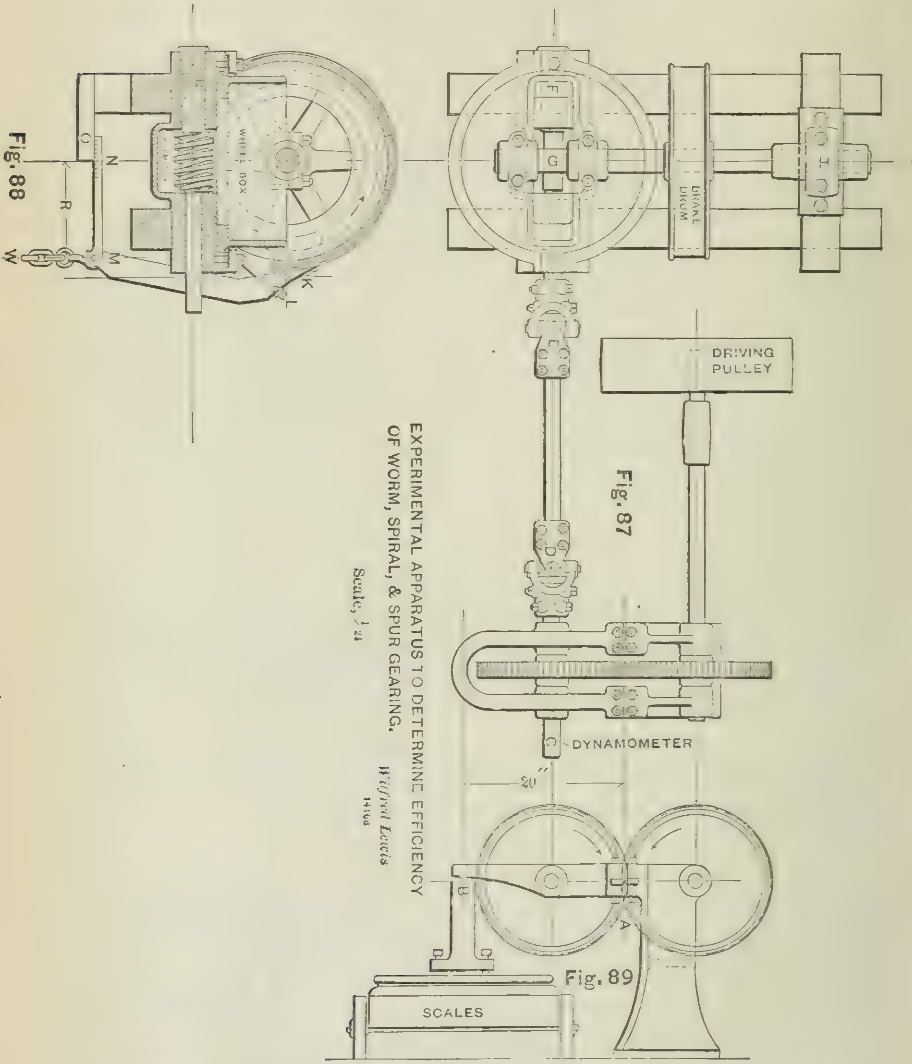
With what success our efforts were attended in the design and execution of the work will appear in the sequel, but at the outset we imagined our apparatus to be well-nigh perfect, and almost incapable of showing anything but the truth.

The principal requirements in the problem presented were a dynamometer to measure the power received by the worm or pinion shaft, and a brake to measure the power delivered to the wheel shaft. These two elements, in their proper relation to the gearing to be tested, constituted the apparatus shown in plan by *Fig. 87*, and in elevation by *Figs. 88* and *89*.

The chief difficulty in the perfection of the scheme lay in the construction of a dynamometer which should not have the errors and defects common to such machines.

* From Advance Sheets, Vol. VII., Transactions A. S. M. E.

We required, in the first place, that it should be readable at any time, with as much delicacy and precision as an ordinary pair of scales; and, in the second place, that its own resistance should,



if possible, be eliminated from its readings, without the necessity of making guess-work corrections.

An experimental dynamometer, similar to the one represented,

was built at the suggestion of Mr. Bancroft, and tested with encouraging results; but, instead of the universal joints, he used simply a straight shaft and depended upon its flexibility, and instead of the frame hinged at *A*, two separate frames were used and the shafts held at a fixed distance apart by means of links.

From a practical point of view, this might have been considered a success, but, theoretically, it was subject to an error arising from the friction of the driven shaft in its bearings. When properly lubricated, this friction would be small, but from carelessness in oiling, it might well be worth considering, and the arrangement shown in *Fig. 87* was designed as an improvement. Here it will be seen that the frame which carries the driven wheel is supported by a flexible joint at the line of contact *A*, and again at *B*, by portable platform scales.

From this construction, it follows that no matter how great the friction in the journals of the shaft *C D* may be, there will be no pressure at the point *B*, except what results from torsion in the shaft *D E*.*

To demonstrate this point, let us imagine the driven wheel firmly clamped to its frame, so that for all intents and purposes it may be considered as part of the lever *A B*. Now, it is evident that a downward force acting on this lever at any point to the right or left of *A*, will produce at *B* a reduction or increase of pressure proportional to the distance of the force applied from *A*. And it is likewise apparent, when a force acts directly in line with *A*, that no portion of it can be communicated to *B*. When this principle is clearly understood, it can readily be seen that journal friction is nothing more than a partial clamping of the wheel to its frame *P*. A thorough test of the accuracy of this construction was made by attaching to the shaft *C* a brake in connection with the frame *A B*. When the wheels were set in motion, this brake represented a magnified case of journal friction, and no matter how tightly it was drawn, the reading of the scales remained unaltered.

As a still further refinement of this dynamometer, the attempt was made to avoid the use of gear teeth altogether and drive by the contact of flat-faced wheels, but the great pressure required to

* This principle is the same which was used by Mr. Tatham in his belt dynamometer.—[W. L.]

drive caused the journals to heat rapidly, and the idea was soon abandoned. Otherwise the method was satisfactory, and the truth of the principle just demonstrated was repeatedly shown by the fact that the reading of the scales could not be altered by any change in the clamping pressure on these discs.

To measure the power transmitted, it was important to know the effective length of the lever arm $A \cdot B$, and this was carefully tested in the following manner and found to agree with actual measurement.

The universal joints were disconnected, the driving pulley was blocked, and a weighted lever attached to the shaft C; the scales were then balanced, and the weight was moved out upon the lever until the reading of the scales was increased by an amount equal to the weight moved. The distance through which the weight had to move was then taken to be the effective length of the lever arm of the dynamometer. The brake used to measure the power transmitted was designed to maintain an approximately constant load of any desired amount. It consisted of a drum or pulley encircled by a Napier brake of rather novel construction, in which the load itself was made to adjust automatically the tension on the strap.

By this means, there were no extraneous forces involved and no corrections to be made, and the error usually arising from the use of an auxiliary tightening lever was avoided.

By reference to the drawing, it will be seen that, for any given load suspended at the point M, the tension on the strap at L depends upon the horizontal distance of M from K, and that the moment of resistance is measured by the horizontal distance R of the point M from the centre of the drum.

As a precaution against excessive heating during the progress of experiments, this brake drum was provided with deep internal flanges forming a trough through which water could be made to pass by means of a siphon.

The gearing to be tested is represented on the drawing as a worm and wheel, but the housings which carry their journals are adjustable, so that the brake shaft can be set obliquely to the worm shaft for spiral gearing, or parallel to it for spur gearing.

The worm box was made very large, to insure an abundance of oil and dissipate as fast as possible the heat of friction. It also

acted as a reservoir for the lubrication of the journal and step-bearings, and as a bath in which a thermometer could be kept to note the temperature from time to time.

Power was received by a belt to the driving pulley from an independent engine, the speed of which was under the control of the experimenter. In preparing for experiments, the shafts $C\ D$ and $E\ F$ were set in line, or nearly so, and the edge of the block O adjusted to be directly under the centre of the drum shaft. Then, with a known weight attached to the chain from M, the worm box filled with lard oil, and the apparatus set in motion, the experiments were ready to begin.

By means of the nut L, the position of the weight was adjusted until the graduated bar $M\ N$, resting on O and M, was brought to a horizontal position. Then the revolutions per minute were counted, the temperature noted, and the reading of the dynamometer observed, together with the distance R on the bar $M\ N$.

In commencing to make the experiments, several unexpected difficulties were encountered, which for a time vitiated the results to an unknown extent. The experiments thus affected, however, were afterward repeated so as to exclude any errors which might have crept in unobserved.

At moderate speeds everything ran smoothly, but as the speed was increased, the step bearing for the worm shaft began to give trouble. This bearing was formed by the contact of two hardened steel discs carefully ground, and although well lubricated by a circulation of oil, the danger of cutting at high speed was constantly to be apprehended.

The delay caused in this way was very annoying, and after a number of futile efforts to lengthen the life of the bearing, the experiment was finally made of introducing a loose washer of hard brass between the hardened steel faces.

This remedy proved to be effectual, and no further evidence of cutting at this point was detected for any combination of speed and pressure.

The brake strap was also at first another source of annoyance. It was made as shown by the drawing of a flat iron strap lined with hard wood blocks on end grain, and for a time it worked well, although not quite as steadily and smoothly as could be desired.

There appeared to be considerable variation in the friction of these blocks against the drum, and the weight suspended was in consequence thrown into oscillations, which had to be checked before the distance R could be properly measured.

To check these oscillations it was simply necessary to press the bar $M N$ against its bearing, until they were absorbed by the friction thereby produced, and so long as a slight amount of oscillation remained, it was considered as evidence that this friction did not effect the mean radius to be determined. Still there were variations in the amplitude of the vibrations which could not be altogether controlled in this way, and for the purpose of improving its action the brake strap was lubricated with a mixture of tallow and oil, which at once produced the most alarming results. The load was thrown into the most violent agitation, and the apparatus shaken in a manner which threatened to break it down. For this strange phenomenon no satisfactory explanation could at first be given. The apparatus was strengthened and braced in various ways, sometimes with an improvement in its general working but oftener without avail. The vibrations were at times very violent, and again entirely absent under apparently the same conditions. Sometimes they increased in violence with the speed, and sometimes they diminished, and finally disappeared.

At or above a speed of 180 revolutions per minute of worm-shaft which corresponded to a surface velocity of about sixty feet per minute at brake surface, these vibrations seldom occurred; but as the wheel slowed down they would almost invariably appear before coming to a full stop. Once they occurred at a speed of 348 revolutions after the wheel had become hot enough to melt the tallow, and their recurrence at this speed was prevented by keeping the wheel cool with water.

At another time, when running at a speed of seventy revolutions with the same load, the vibrations continued for several hours, and were finally checked by allowing the wheel to warm up. The speed was then reduced to three revolutions, at which it ran without shake or jar, but five minutes later, upon starting up, the vibrations were as severe as ever and could not be made to disappear, even at a speed of seventy revolutions.

The wooden blocks were then scraped and washed with benzine to remove all grease, with, it was thought, some improvememt, although at slow speeds, the vibrations still continued.

In general, it was found that slow speeds and heavy weights had the greatest tendency to produce vibrations, and that the heavier the load the greater the speed necessary to check them. At slow speeds their amplitude was greatest and their number the least, while as the speed increased, they became shorter and more rapid, producing a higher and higher tone until they finally ceased.

The phenomena presented were so strangely contradictory that for a time they seemed to defy explanation, and seriously to threaten the success of the undertaking.

The only plausible theory upon which they could be accounted for appeared to be, that the frictional surfaces were in an unstable condition, caused by the difference between friction of rest and friction of motion.

With most substances the friction of motion is less than the friction of rest, and it was argued, that by reason of the friction of rest, the brake strap would be carried beyond the point where it belonged, to be in equilibrium with the friction of motion, and when sliding occurred, it would fall back and grip the wheel with such force as to stop all sliding and again produce friction of rest.

Having failed to secure a satisfactory brake surface of wood it was decided to try another material, and from the view of the case just presented, leather suggested itself as the most suitable substance, on account of its peculiar frictional properties, which make it an exception to the general rule, that friction of motion is less than friction of rest.

Accordingly, each block of wood was covered with a leather face, and all further difficulties of this kind were effectually checked.

During the long series of experiments which were afterward made, a slight tremor was sometimes noticed when the wheel became hot enough to dry up the leather, but at such times the original condition was easily restored by the application of a moderate amount of belt grease.

Too much of the lubricant was found to be injurious, and no more was needed than could be absorbed by the leather. It was also noticed, that on account of the increase in friction of the leather over the wooden surface, the brake was more easily adjusted, and that the weight suspended from it hung, in consequence, farther from the centre of the drum shaft.

It could hardly be expected that a weight suspended in this manner from a rotating wheel would remain motionless, and very naturally it was found that oscillations of gradually increasing amplitude were to be constantly contended with. The disturbing cause, however, was so slight that the friction produced on the guide O, by a weight of one pound resting upon the graduated bar $M N$, was found to be sufficient to reduce the variation in its readings to one-sixteenth inch. The apparatus was now thought to be entirely satisfactory and the experiments were begun anew.

The readings of the graduated bar were taken to the nearest one-sixteenth of an inch, and they were considered accurate within that limit, which in a radius of fourteen inches, gives a probable error of less than ·005. During the progress of an experiment this radius was subject to gradual changes, which were generally accompanied by corresponding changes in the reading of the dynamometer.

The readings of the graduated bar and dynamometer were, however, always taken at the same instant, and as a matter of possible importance the temperature of the oil in the worm box was also recorded by a thermometer constantly immersed.

The dynamometer was sensitive to a variation of half a pound, and the readings for average cases were probably taken within ·01 of their true amount, the error in observation being greater for light loads and less for heavy ones.

It was not suspected until the experiments were about to be concluded, that the dynamometer itself was liable to any error at all, and it was then discovered, when too late, that it had a constant error of about two per cent., which was either positive or negative according to the alignment of the universal joints.

It will be explained further on how this error was detected and the causes which produced it, but in view of the great variations found in experiments made under similar conditions, it was not thought necessary to attempt to make any correction. Indeed, this could not have been done without a repetition of the whole work, and the experiments are accordingly presented as subject to an error of two per cent.

The probable errors in observation are not included, because it is not to be supposed that the average of so large a number of experiments could be much affected by errors in observation, unless

these errors were necessarily in one direction, as in the case just cited.

The merits and defects of the apparatus have been thus reviewed at length, partly for their own intrinsic worth, but chiefly as matters of the first importance to a clear appreciation of the real value of the experiments.

It is intended to give not merely the bare results, but also the facts upon which a judgment or criticism of them can be formed, and this is our apology for what may seem like unnecessary detail.

Having overcome the difficulties thus far enumerated the experiments themselves were continued.

Weights were suspended from the point *M*, ranging from 256 to 4,000 pounds, and the worm shaft was run under these loads at speeds ranging from three to 880 revolutions per minute. A great variety of conditions were thus obtained, and covered by about 800 experiments.

These conditions involved four variables, namely, speed, pressure, temperature, and state or nature of the rubbing surfaces.

The speed and pressure were the primary conditions adjusted by the operator, and the temperature and state of surfaces were secondary, and dependent upon the duration of the experiment as well as upon their primaries. The importance of the latter variable was not discovered until about half of the experiments were completed, and then it could be judged of only by its effects

The experiments have been divided into series, each representing a special set of gearing tested.

In every case the material used was cast iron, and to facilitate comparisons the wheels and pinions were all made as near as possible to the same dimensions.

The first series was made upon a double-thread worm, four-inch diameter, gearing with a worm wheel of thirty-nine teeth, one and one-half inch pitch, the thrust of the worm being taken on its annular surface instead of upon the step bearing used in other series. The remaining series upon this form of gearing were made upon worms having cast and cut teeth of single and double threads, all of the same pitch and diameter, gearing with the same diameter of wheel. Four series were made with spiral pinions four-inch diameter, one and one-half inch pitch, having respectively one, two, four and six teeth, gearing with a spur wheel of thirty teeth,

and one series with a spur pinion of twelve teeth, one and one-half inch pitch, gearing with the same wheel.

From the great mass of data obtained in this way, it became necessary to deduce some general conclusions by which the efficiency of any system of gearing could be determined.

The foundation for this work was taken to be the efficiency of the apparatus used. This was computed for every experiment by two persons independently, and their results were compared and corrected by a third, so that the possibility of errors in calculation should be reduced to a minimum.

The method of computation was very simple, but the labor involved by so many experiments was very great. The efficiency of the apparatus was in each case determined by dividing the moment of the dynamometer into the moment of resistance.

The moment of resistance was measured by the product of the weight suspended at M into the distance R, plus an additional amount for the moment of the brake itself, and the moment of the dynamometer was measured by the product of its record into the distance $A\ B$ times the ratio of the gearing used.

The efficiency was at once seen to depend principally upon the speed, and within limits, the higher the speed the greater the efficiency. But there were other disturbing elements, including temperature, pressure and state of surfaces, the combined effects of which produced many exceptions to this general rule.

At very high speeds, the rubbing surfaces were more liable to cut, and beyond certain points which could not be definitely determined, the efficiency appeared to diminish.

In different cases, variations of temperature and pressure were accompanied by such contradictory results that no generalizations could be made concerning them.

As already stated, the condition of the rubbing surfaces could be judged of only by its effect. At certain speeds and pressures the efficiency would slowly increase to its maximum, while at others it would suddenly diminish and indicate the destructive action known as cutting.

Upon examination this destructive condition did not always become apparent to the eye, and in some cases the apparatus was taken apart and cleaned, without making any decided improvement in efficiency, but it was finally discovered that in such cases

it was necessary, to restore the surfaces to their best condition by running for some time at a moderate speed and pressure. From this it appeared that the order in which the experiments were made, had an important bearing upon the results obtained, and it also furnished a satisfactory explanation for the contradictory appearance of many experiments which were otherwise made under apparently the same conditions.

Throughout one-half of these series no attention was paid to the order of the experiments, their sequence being guided entirely by convenience. The main object at first was to discover the efficiencies corresponding to variations in speed, pressure and temperature, and to determine a definite limit beyond which the speed of worm gearing could not be carried to advantage.

The injurious effects of high speeds upon succeeding experiments were not at first noticed, and a number of series are thus intermixed with exceptional cases arising from this cause, while in others the destructive conditions appear to form a separate group.

Having found the limiting speeds and pressures for worm gearing, care was taken in the remaining series to avoid them as far as possible, and by this means to secure some very good and harmonious results.

In order to present the experiments in a convenient shape for generalization and practical use, the attempt was made to tabulate them with reference to the speed as the most important variable. But the tabular method proved to be inadequate, unwieldy, and difficult of application to other cases, and in its place was substituted a graphical method, by which the efficiency and attendant conditions in each series could be seen in a much more comprehensive and instructive manner.

The results of each series herewith presented have been carefully plotted to scale, making abscissas proportional to the logarithms of the revolutions per minute and ordinates proportional to the efficiency of the apparatus.

This peculiar method of constructing the abscissas was adopted because it was seen that increments in efficiency were more nearly proportional to the ratio of the speeds than to their actual differences.

Different symbols are used to denote different pressures on teeth, and each symbol is numbered to show the order in which

the experiments were made and the temperature of the oil in the worm box.

These symbols are connected so as to form lines of efficiency corresponding to the various pressures used, and the average of all these lines is taken as the average for the whole series.

The first series of experiments graphically represented in *Fig. 90* was made upon a double-thread worm four inches diameter, gearing into a worm wheel of thirty-nine teeth one and one-half inch pitch.

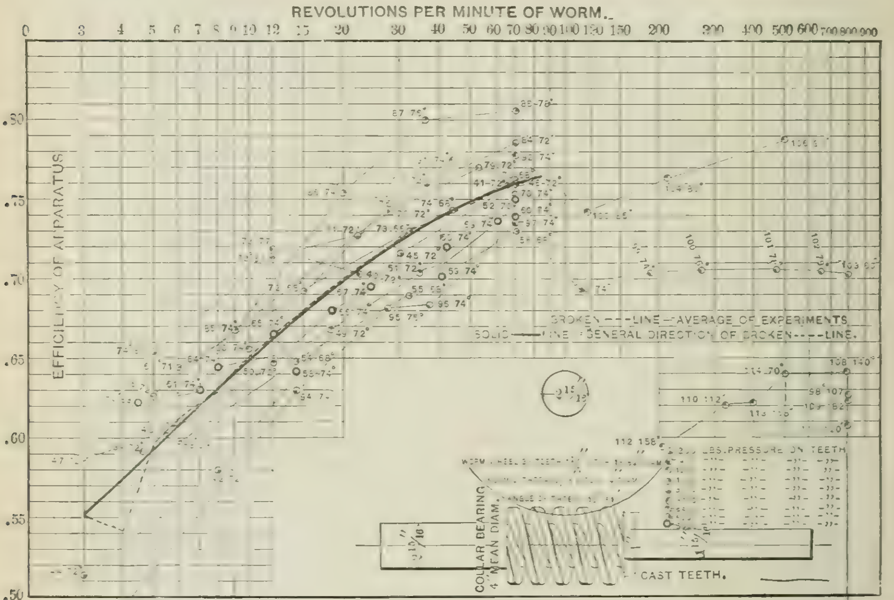


Fig. 90

There are 114 experiments which cover a range of speed from three to 790 revolutions per minute, and loads up to 4,000 pounds upon brake wheel.

The worm and wheel had cast teeth, and the thrust of the worm was taken upon the worm itself instead of upon the shaft step, as in the subsequent series.

Of these 114 experiments the first thirty-eight have been omitted as preparatory on account of difficulties already stated, and the diagram begins with experiment thirty-nine, when the leather lagging on brake strap was first used.

The first sixty-two experiments were made with the disc dynamometer, and from there on, gear wheels were used to diminish journal friction.

The diagrams herewith presented give the essential results obtained, and it will only be necessary in connection with them to notice some peculiarities.

Considerable variation in the efficiency of the apparatus at any given speed will be observed on all diagrams, but more especially upon those for worm gearing, where, as already stated, no attention was paid to the progressive order of the speeds and loads.

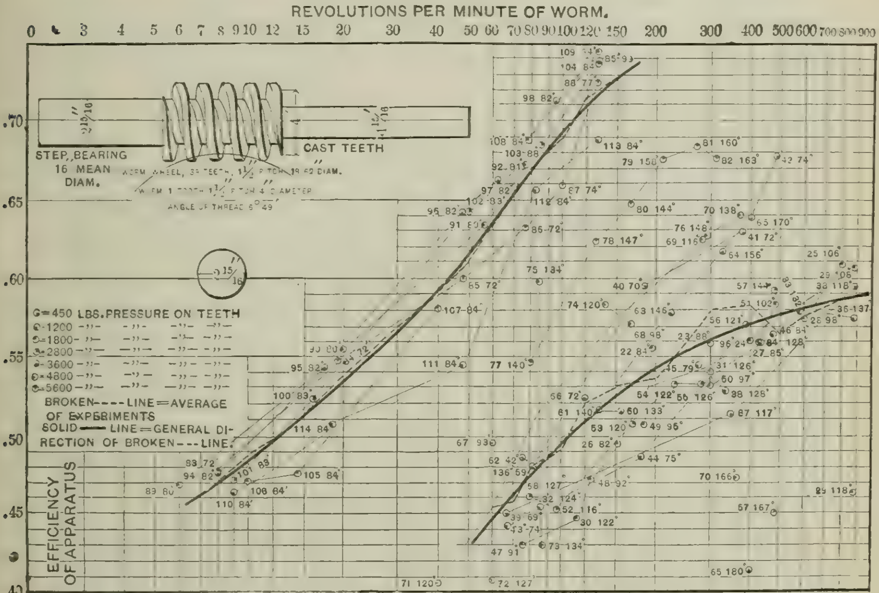


Fig. 91

In *Fig. 90*, the bulk of the experiments were made between the limits of three and seventy revolutions per minute, for, in order to obtain the higher speeds, it was necessary to make a change of pulleys, and, fortunately, this was not done until the experiments on the lower speeds were completed.

Between the limits just mentioned, the general direction of the lines of efficiency is strongly marked, and the group forms a band of nearly uniform width, extending over about ten per cent. of variation. At the higher speeds the results are very much scattered and give unmistakable evidence of cutting.

This series was unexpectedly brought to a close by the breaking of the worm teeth, which were found to have been entirely ground away. The wheel, however, was in good condition, the wear having been just sufficient to polish the surface of the teeth.

The second series of experiments was made upon a single thread cast worm and wheel, the thrust being taken on the step at end of worm shaft. In this series, also, the experiments appear to form themselves into separate groups, and the same phenomenon will be noticed on *Figs. 92, 93* and *98*, and in all cases where the destructive conditions depending upon speed, pressure and temperature have not been carefully avoided.

So long as the condition of the rubbing surfaces is unimpaired, the efficiency appears to increase with the speed, and even after cutting has begun, the same general tendency will be observed, although starting from a lower point on the diagram.

The principal object in this series was to determine the limiting speeds and pressures at which the worm could be run without danger of cutting. These speeds were also found to depend upon the temperature and duration of the experiment, and they were, consequently, not clearly defined; but, in general, it was noticed that at slow speeds the greatest efficiency was found under the heaviest pressures, at moderate speeds under moderate pressures, and at high speeds under light pressures. This seemed to point toward a limiting product of speed and pressure, beyond which the heat of friction became generated so rapidly as to impair the condition of the surfaces in contact and produce cutting.

The following table shows the conditions under which cutting was found to take place within periods of ten minutes. In all cases, the precise time at which cutting occurred was marked by a sudden rise in the reading of the dynamometer, and from the reading at that time the final efficiencies were computed. In the last experiment no cutting took place, as shown by the constant efficiency of ·677.

SPEEDS AND PRESSURES LIABLE TO PRODUCE CUTTING.

Velocity of Sliding in Feet per Minute.	Pressure on Teeth.	Temperature.		Efficiency.		Duration of Run in Minutes.	Foot-Pounds per Minute consumed in Friction before Cutting began.
		Initial.	Final.	Initial.	Final.		
800	1785	106°	140°	·609	·387	6	117,600
880	1780	118°	132°	·607	·462	3	129,300
880	1205	137°	150°	·575	·360	3	97,000
800	448	118°	133°	·594	·445	10	29,400
480	2822	144°	167°	·591	·450	7	117,800
400	3481	170°	180°	·639	·415	3	98,300
360	4837	138°	166°	·641	·473	6	122,400
306	5558	163°	186°	·677	·677	10	102,000

It appears, from this table, that the danger of cutting does not depend entirely upon the amount of frictional work, and it is not easy to understand why this should be the case, but the fact remains, and we are forced to conclude that very high speeds should be avoided, even under light pressures, and that the best working conditions are to be looked for at or below 300 revolutions per minute, which corresponds to a surface velocity of sliding of about 300 feet per minute. A great deal, of course, depends upon the rapidity with which the heat of friction can be conducted away.

For the apparatus used, it was determined that when one horse-power was consumed in friction, the worm-box remained at a uniform temperature of about 50° above the surrounding air, and, assuming the rate of cooling to be proportional to the difference in temperature, it seems improbable that more than two horse-power could be continuously consumed in friction without overheating the lubricant.

In plotting the diagrams care has been taken to exclude from the general result the worst and most evident cases of cutting, such as those just given in the table.

The third series, represented in *Fig. 92*, was made on gearing similar to that used in the first series, with the exception that the thrust of the worm was taken upon the step at end of worm shaft instead of upon the annular end of the worm itself. At the conclusion of this series, the step bearing was found to be in good

condition, the rubbing surfaces having worn to an annular bearing of, say from one to three inches diameter.

The worm shaft and its bearing at large end, however, were badly cut, and, judging from the record of the experiments, the cutting must have occurred near the middle of the series, thereby reducing the efficiency of the latter half of the experiments, and furnishing an explanation for the discrepancies between this and the first series. In this series the limiting pressure for a speed

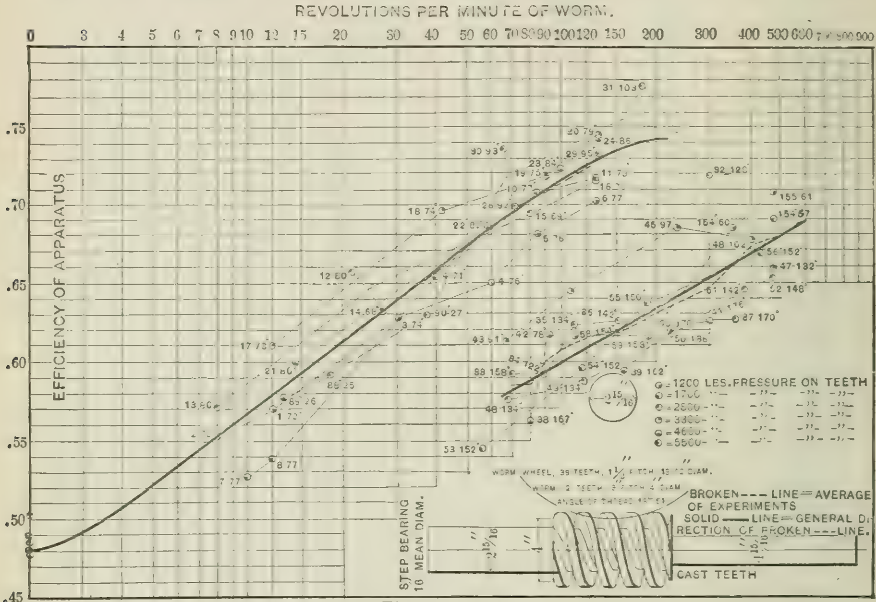


Fig. 92

of 300 revolutions appeared to be about 4,500 pounds for a run of five minutes.

A pressure of 5,600 pounds at a speed of 280 revolutions per minute and temperature of 190° produced cutting in three minutes, but whether on the teeth or in the journals it was never possible to determine without taking the apparatus apart at the sacrifice of considerable time. But this cutting would naturally be supposed to take place sooner on the teeth where the intensity of pressure was greater.

One more series, the ninth in order, represented in *Fig. 98*, completes the experiments upon worm gearing. This was made

upon a worm and wheel similar in every respect to those used in the second series, except that the teeth were cut instead of being cast. The speeds, however, were kept below the limits found by previous experiments to produce cutting, and the temperatures were consequently moderate, ranging from 48° to 116° in extreme cases. In this way the rubbing surfaces were kept in good condition throughout, and the results are altogether more satisfactory than any yet recorded.

The break in the line of efficiency at the higher speeds is not due in this series to their injurious effect, but to the fact that the precaution of running the apparatus for some time before commencing to note experiments was accidentally neglected.

It had been previously observed that under moderate speeds and loads, the efficiency of the apparatus would continue to improve until a maximum limit appeared to be reached, and, in order to obtain observations under the best working conditions, a rule had become established not to begin noting down experiments until after the apparatus had been warmed up once or twice in running.

For all speeds below 100 revolutions, however, the curve shown on *Fig. 98* may be accepted as very near the truth, and, by comparing this with *Fig. 91*, it seems probable that with both sets of gearing in their best working condition, these lines of efficiency would practically coincide.

From the experiments made to determine the limiting speed and pressure at which worm gearing can be run successfully, we conclude that when the gearing is loaded to its working strength, it is not safe to exceed a velocity of sliding of 300 feet per minute, and that, in general, the best working conditions are obtained at or about a velocity of 200 feet per minute. The experiments upon spiral gearing begin with *Fig. 93*, which shows the efficiency of a one-toothed pinion gearing with a spur wheel of thirty-nine teeth one and one-half inch pitch.

In these experiments, the shaft $G H$ was set around at an angle of 6° 51′, so that the teeth of the spur wheel should gear properly with the pinion. The results obtained show a constant improvement in the condition of the rubbing surfaces throughout the series, and clearly indicate the necessity just mentioned, of running the apparatus for some time before taking observations. Here the

slow speeds were taken first before the teeth were worn to a good bearing, while in the ninth series the circumstances were reversed. In both series the condition of the surfaces underwent considerable change, and the results are to that extent not as satisfactory as could be desired. Upon repeating some experiments at the conclusion of this series, it was noticed that the efficiency had improved nearly ten per cent., and the broken line on the diagram

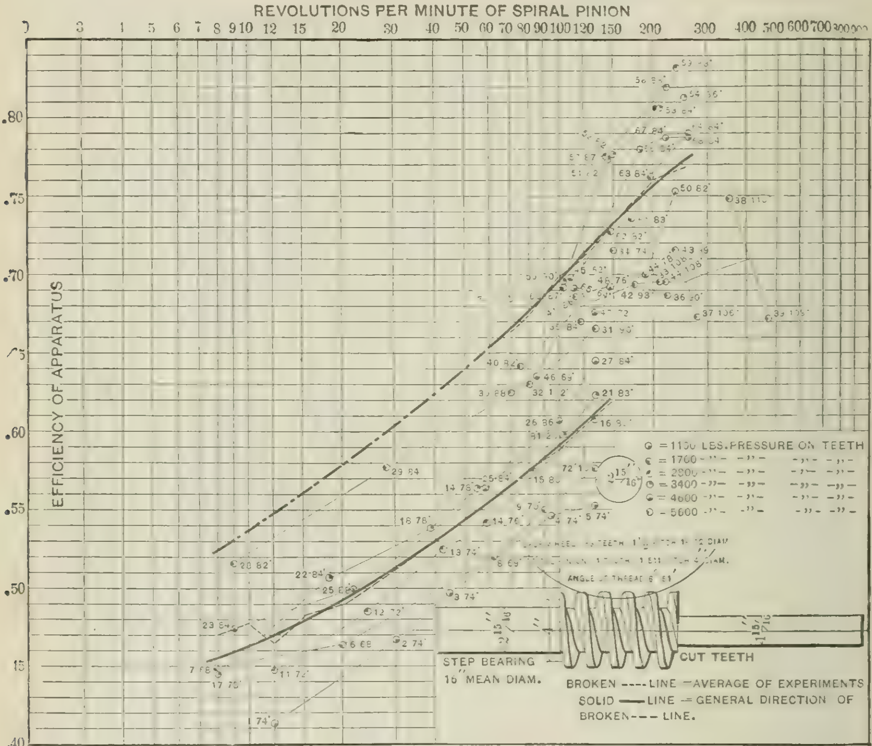


Fig. 93

was drawn to show the probable position of the curve, had the precautions alluded to been observed. Theoretically, the efficiency of the spiral gear should have been a trifle better than that of worm, on account of a slight diminution in the velocity of sliding, and had this series been repeated, it would undoubtedly have so appeared. The teeth used in this gearing were accurately cut to an epicycloidal shape, and in all cases their action in rolling contact was practically perfect, while with the worm gearing the shape

was rather indefinite, presumably involute, but the patterns for the wheels were made by a cutter, like the worm itself, and the two were necessarily obliged to fit.

The fifth series was made upon a spiral pinion of four teeth, with the shaft *G H* set around at an angle of 28° 31′. In this, as well as the following series of experiments upon spiral pinions, the apparatus was run at a moderate speed and load, until the rubbing surfaces were thought to be in their best working condition, before any records were taken, and as a result, the diagrams will be found

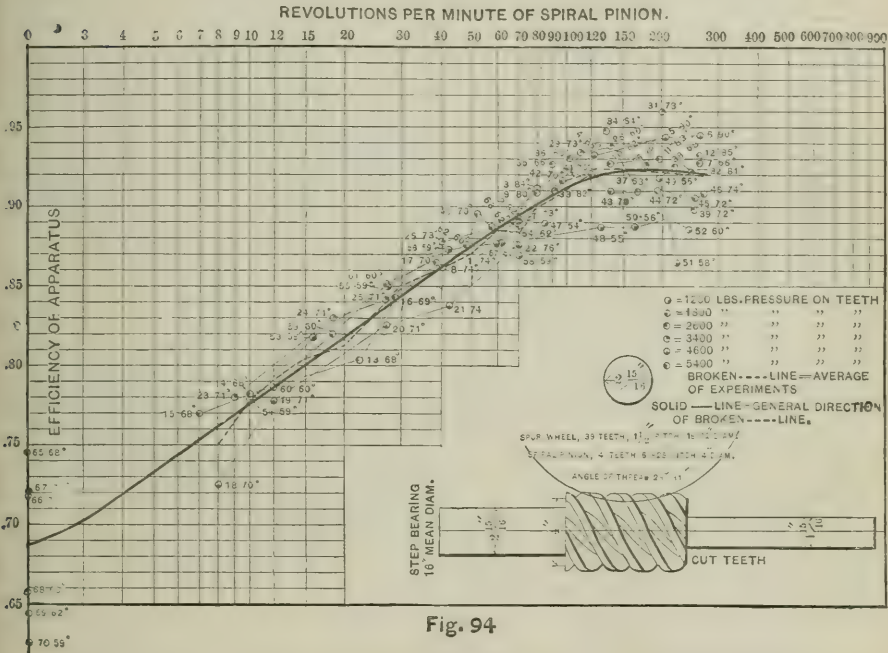


Fig. 94

to be more definite and conclusive than anything heretofore shown. The speeds ran just high enough to show that the limit had been nearly reached, but no well-defined case of cutting occurred, and the experiments may be regarded as having been taken under the best working conditions.

The sixth series was made upon a spiral pinion of two teeth, with the shaft *G H* set around at an angle of 13° 49′. Here also the results obtained are remarkably progressive, and free from all evidence of cutting. A comparison with similar experiments upon

the double-thread worm shows a great gain in efficiency—which cannot be credited entirely to the improved action of the gear teeth, but which must also be accounted for by the fact that destructive speeds were avoided, and that the apparatus was maintained throughout in good working condition.

The seventh series, upon a spiral pinion of six teeth with the shaft *G H* set at an angle of 45° 44′, also gives very good results, and these three series, *Figs. 94, 95* and *96*, might be taken as a

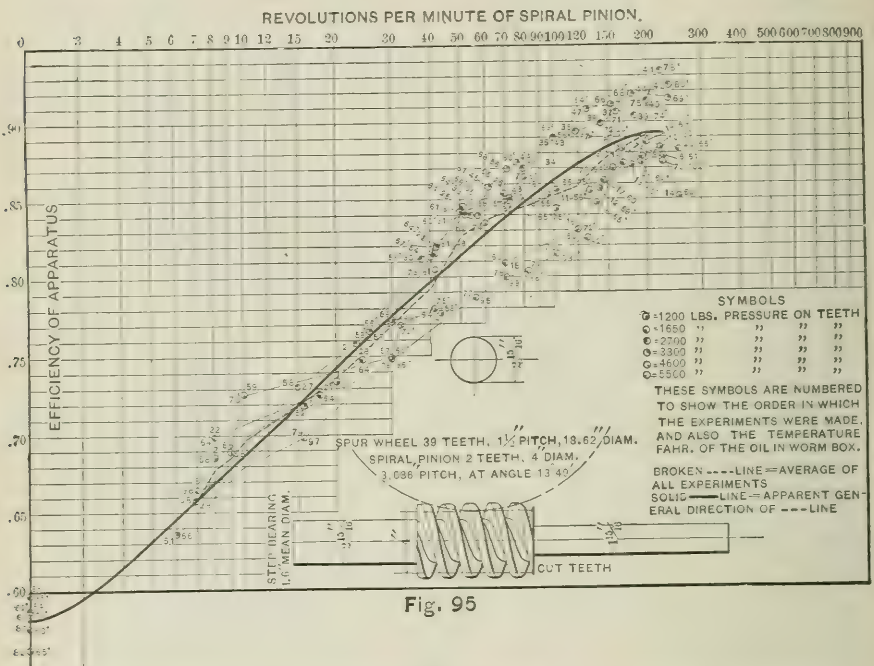


Fig. 95

basis upon which to determine the laws of friction for spiral gearing in general.

To make a complete analysis of these results, it would be necessary to eliminate the friction of worm shaft and drum shaft from that of the teeth themselves, and determine the coefficient of friction for a number of different velocities of sliding.

An effort was made to do this by running these shafts under known journal pressures, but the results obtained were of such an indefinite and contradictory character that the task seemed hopeless, and it was not until after the completion of the eighth series

that a method was adopted by which the efficiency of any set of gearing could be approximately determined. For practical convenience the efficiency of the whole apparatus may be considered as equal to that of any other similar piece of gearing, and, as a matter of fact, the relative dimensions of the various parts do not differ a great deal from those used in these experiments.

The wheels might be larger or smaller, but the diameters of spiral pinions and worms generally bear about the same relation to their shafts, and it is in these parts that the principal work of friction is consumed. When the angle of a worm or pinion and

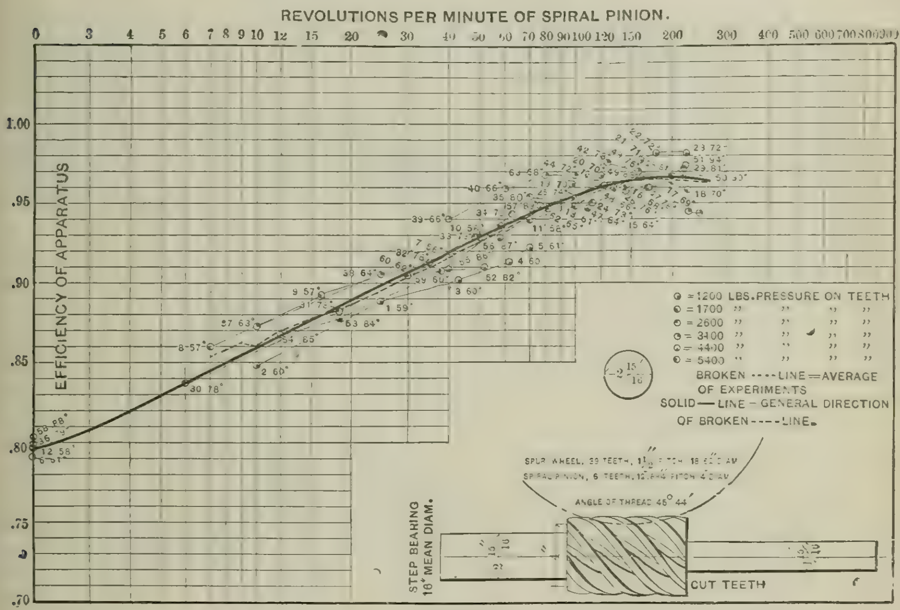


Fig. 96

its speed are given, it should be possible, from these experiments, to fix at once with tolerable accuracy the efficiency of the gearing to which it belongs.

This can now be done for the angles experimented upon, but we shall presently show how, by the method alluded to, the efficiency may be determined for any angle whatever.

The eighth series (*Fig. 97*) was made upon a cut spur pinion of twelve teeth one and one-half inch pitch, with the shaft *G H* set parallel to the pinion shaft. In this series an error, already mentioned, was discovered in the readings of the dynamometer. The

efficiencies, as calculated from the record of experiments, were in some cases found to exceed 100 per cent., and these results were repeatedly confirmed by experiments.

Numerous efforts were made to locate the error without success, until finally it was remembered that the accuracy of the instrument was predicated upon the assumed flexibility of the universal joints. It was also thought probable that however carefully adjusted the shafts *F E* and *C D* might be, they would no doubt be somewhat out of line, and that consequently the universal joints would be forced to swivel slightly under pressure. Should the

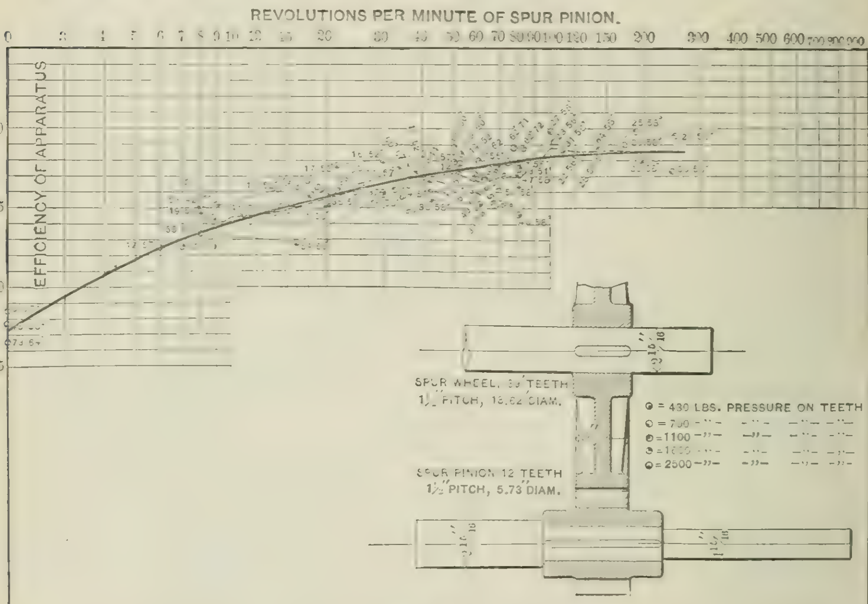


Fig. 97

error be due to this cause it was expected that by moving the shaft *F E* parallel to itself for a short distance to either side of the centre line of *C D*, the efficiency would appear to be alternately above and below its true value by an amount due to the stiffness of these joints.

The shaft *E F* was accordingly moved about one inch from the centre line in either direction and a number of experiments were made in each position, the result of which showed a total variation of about ·04 in the average efficiencies as determined for each position and speed.

For a speed of twenty revolutions the efficiency varied from ·944 to ·993 according to the position of *E F*, and the true value was accordingly estimated at ·968, the arithmetical mean. Similarly the efficiencies at a speed of eighty revolutions, varied from ·966 to 1·016, giving ·991 for the true value at this speed.

The eighth series, as plotted upon *Fig. 97*, represents the mean of two sets of experiments conducted in this way, and the errors due to the stiffness of the universal joints are consequently eliminated. It should be observed in regard to this error, that its

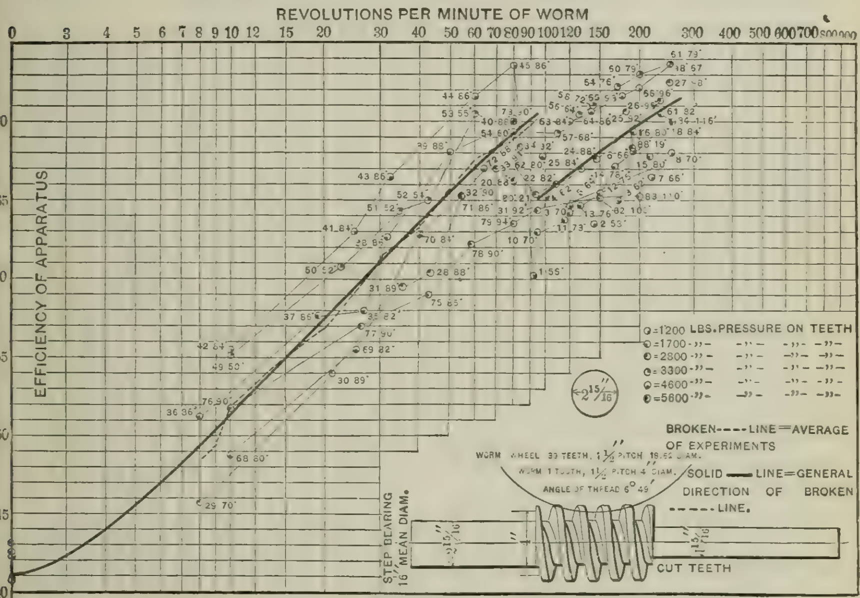


Fig. 98

actual amount is proportional to the efficiency itself, or, in other words, that the error is two per cent. of the efficiency and not an actual difference of two per cent. more or less, and for this reason it may be said there was less necessity for its correction in any other series than there was in this. An approximate analysis of the loss in effect presents fewer difficulties in this series than in any other, but still it is necessary to make certain hypothetical assumptions which cannot as yet be substantiated. This loss in effect may be considered as composed of three parts, the friction of two journals and the intervening gear teeth.

If we assume the loss in each case to be proportional to the product of the pressure and amount of sliding, we have the pressure on pinion shaft equal to the pressure on teeth, and the pressure on drum shaft about fifty per cent. greater, owing to the resultant from load suspended.

The amount of sliding per revolution of pinion shaft is about 7·5 on pinion shaft, 3 inches on teeth, and 3 inches on drum shaft, and the product of these numbers times the pressure in each case gives the relation of 7·5, 3, and 4·5, the sum of which is 15. Of this total effect the friction of the gear teeth consumes ·2.

Therefore, it appears on this assumption, that the principal loss in effect with spur gearing is from journal friction.

The experiments which were made to determine the friction of the worm shaft under the various loads and speeds, showed for a pressure of 800 pounds, coefficients ranging from ·15 at the start to ·006 at speeds between 110 and 240 revolutions per minute, and for a pressure of 3,440 pounds, coefficients ranging from ·12 at the start, to ·033 at a speed of 240 revolutions per minute.

This irregularity under different loads made, as already observed, so much difficulty in determining the loss in effect from journal friction, that the attempt to eliminate it was at first abandoned, but, after the completion of the eighth series it was thought that inasmuch as the principal loss was there due to this cause, this series itself might be made the basis upon which to eliminate the effect of journal friction in others.

We will therefore assume for this series that the loss in effect from journal friction is ·8 of the total amount of loss. The loss from this source in other series has been roughly estimated to be nearly the same, and proceeding from this stand-point we can find the probable coefficients of friction for the pinions used in the fifth, sixth, and seventh series.

The efficiency of the apparatus, E, plus L, the loss in effect from journal friction gives the efficiency of the spiral pinion and its step. From this we can find the coefficient of friction by assuming the coefficient for step friction to be the same as for the teeth themselves.

Let $\alpha =$ angular pitch of spiral pinion.

$\varphi =$ coefficient of friction.

$n =$ ratio of mean diameter of step to pitch diameter of pinion $= \cdot 4$.

Then it can readily be shown that

$$E + L = \frac{1}{1 + (1 - n)\,\varphi \cot \alpha} \qquad (1)$$

whence

$$\varphi = \frac{1 - (E + L)}{(E + L)\,(1 - n) \cot \alpha} \qquad (2)$$

From these formulæ a number of coefficients have been calculated, and their values given in the following table, from which it will be seen that the coefficients agree as closely as could be expected, and thereby indicate to a certain extent an harmonious relation between the curves employed in their determination.

Revs. of Pinion.	*E* 8th Series.	*L*	*E* 5th Series 4 Teeth.	*E* 6th Series 2 Teeth.	*E* 7th Series 6 Teeth.	ϕ 5th Series 4 Teeth.	ϕ 6th Series 2 Teeth.	ϕ 7th Series 6 Teeth.	Average Value of ϕ.
3·	·90	·08	·70	·59	·81	·105	·086	·094	·095
5	·92	·064	·73	·63	·83	·097	·078	·089	·088
10	94	·048	·774	·685	·86	·081	·064	·076	·074
20	956	·035	·817	·741	·89	·065	·050	·061	·059
50	·973	·022	·876	·813	·93	·042	·035	·038	·038
100	·982	·014	·912	·862	·955	·030	·025	·024	·026
200	·984	·013	·923	·892	·967	·026	·018	·015	·020

The discrepancies are really not so great as they appear when we consider the variations in the experiments themselves, and the practical impossibility of obtaining very accurate results.

The average of these coefficients, it was thought, would represent, as nearly as possible, the best general results of the whole course of experiments; but upon still further comparison with the best parts of the other series, it was concluded that the sixth series itself formed a better standard from which to deduce hypothetical curves of efficiency for other pinions not included in the experiments. In this series, the probable error in these coefficients was less than in either of the others, because the pinion and step consumed a larger proportion of the total loss in effect, and had the series upon the single tooth pinion been made with equal care, the error would have become still less.

We are well aware that the method just employed for the determination of these coefficients is open to criticism, but when judged by the character of the data with which we had to deal, we believe it to be as refined as the conditions would permit, and however faulty it may be in theory, it is evident that by reversing the process we can reproduce from these coefficients the original curves from which they were deduced.

The effort has been to find some law, by analysis if possible, or by trial, if necessary, which would cover the best portions of all the experiments. In this we have failed to obtain sufficiently accurate data for a complete analysis of the problem, and we have reluctantly been obliged to feel our way by the aid of assumptions whose merits were largely founded upon the results which they afterward brought about.

We have assumed, for instance, that the loss in effect from journal friction is the same for all series, that the coefficients for different portions of the apparatus are alike, and that the velocities of sliding for the different pinions were equal, to all of which exceptions might very properly be taken, but the results obtained upon these assumptions have agreed so well with each other that, for the present, we are obliged to accept them as correct, at the same time hoping that there may be enough interest awakened in the subject to lead to a better understanding of it in the future.

In order to put the results of these experiments in the best shape for practical use, a number of curves have been computed and plotted in *Fig. 99*, from which it is easy to find by interpolation the efficiency corresponding to any angle and speed of pinion.

To illustrate the practical use of this diagram, let us consider the following train of gearing and proceed to find its efficiency. Given a spur pinion driving a spur wheel, upon the shaft of which is a spiral pinion of 30° angle, driving another spur wheel upon whose shaft is a worm of 7° angle, driving a worm wheel.

When the speed of the first shaft is known, it is easy to find from the dimensions and ratio of the gearing, the velocity at pitch line of each pinion or worm. We will assume 200 feet per minute for the spur pinion, 50 feet per minute for the spiral pinion, and 10 feet per minute for the worm, and by reference to the diagram we find ·985 for the efficiency of the spur pinion ·902 for that of the spiral pinion and ·53 for that of the worm.

The efficiency of this train of gearing is therefore

$$\cdot 985 \times \cdot 902 \times \cdot 53 = \cdot 471.$$

For speeds above 200 feet per minute it is recommended to estimate upon the efficiency at that speed.

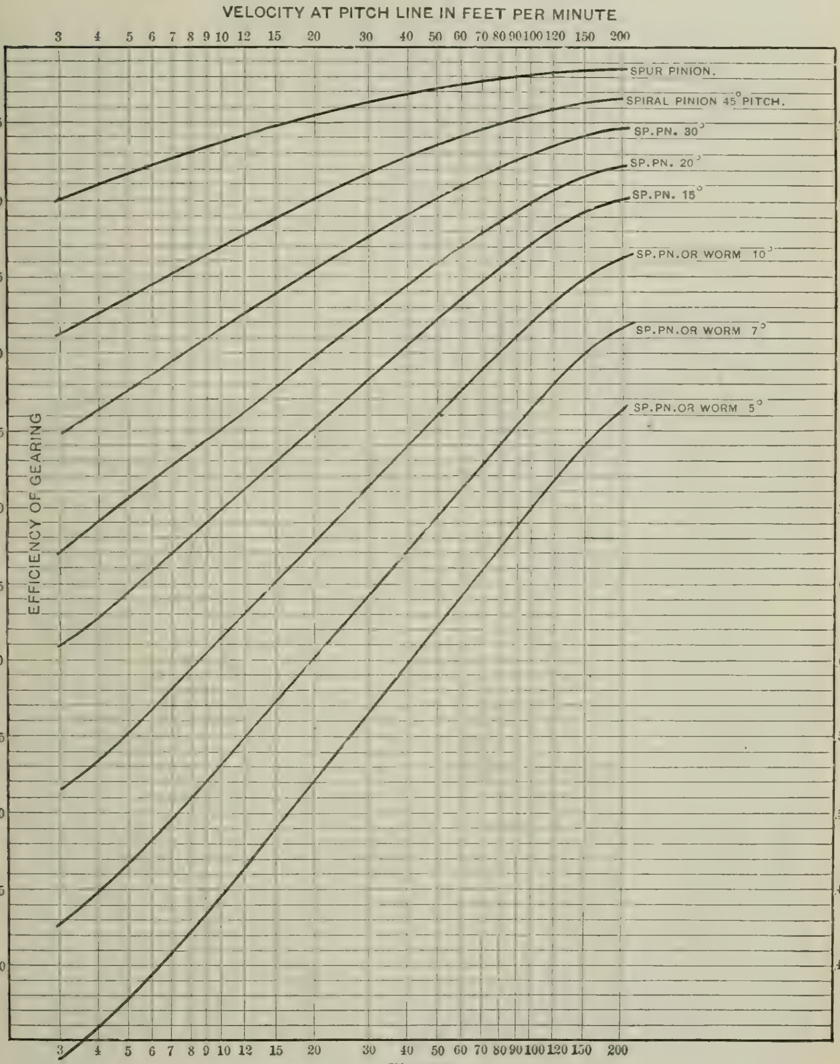


Fig. 99

From the coefficients as determined for the sixth series, $E + L$ can be found by substitution in the formula.

$$E + L = \frac{1}{1 + 1{\cdot}4\, \varphi \cot \alpha}$$

and the value of E is then easily determined by subtracting the value of L, as just given in the table.

The curves determined for 5°, 7° and 10° spiral pinions may be used equally well for worms, and they have been so marked. If we let E = efficiency of a spiral pinion, and E_1 = efficiency of a worm having the same angular pitch, then it can be demonstrated that

$$\frac{E}{E_1} = \frac{\cot \alpha}{\cot \alpha - \varphi}$$

as far as the friction of the teeth alone is concerned, and for small angles this relation is so near unity that the difference is practically inappreciable.

Theoretically, for worms of 20° pitch, the difference in efficiency for the teeth alone should not exceed ·03, but the side thrust on worm wheel would probably increase the friction considerably if larger angles were used.

Additional experiments, not shown on the diagrams, were made to determine the efficiency of spur gearing, in which the reduction corresponded more nearly with that of the single and double-thread worms. For this purpose, the driving gear of an old forty-eight-inch lathe which had been for many years in use, and consequently represented the best attainable conditions, was called into requisition. This lathe was provided with double-back gears which gave, respectively, reductions of 38·4 and 10·2 to 1. The counter-shaft was driven by the dynamometer, and the power transmitted was measured by the brake, already described, carried between the centres. The efficiency of the lathe was measured for every speed under different loads, the average results of the test showing that for a reduction of 10·2 to 1 the efficiency was ·952, and for a reduction of 38·4 to 1 the efficiency was ·935. The power required to run the lathe empty was, of course, excluded in the calculations, otherwise the efficiencies would have had a different value for every load, becoming almost *nil* for light loads and approaching the figures given for heavy ones such as the lathe was expected to carry.

These experiments showed conclusively the advantage of spur gearing over all other kinds in point of efficiency and durability, for not only is there less friction, and consequently less wear, but the wear in spur gearing is distributed over a great deal more surface.

In conclusion it may be said, that the whole subject of friction is dependent upon such a variety of changeable conditions that it is almost impossible to separate and determine the effect of each independent variable apart from others which attend it. The four variables—speed, pressure, temperature and condition of surface—are susceptible of infinite combinations, and even if it were possible to measure the effect of each independently, it is quite probable that the effect of any given combination would not follow from that of each component factor.

To give some idea of the extent of these experiments and the time and care spent in arriving at the results herewith presented, it may be stated that the experiments began on the 8th of August, 1883, and were not completed until January 14, 1884, that fully six months were consumed in the design and construction of the apparatus, and as many more in working up the records obtained.

That they were not more completely successful is due to the fact that we attempted too much at first, and only learned by experience the influences which operated to impair the results.

AURORA SOUNDS.—In March, 1885, Sophus Tromholt despatched some thousand circulars to all parts of Norway containing different queries regarding the aurora, and amongst them also the following: "Have you or your acquaintances ever heard any sound during aurora, and, in this case, when and in what manner?" Up to September 16th, he had received answers to these queries from 144 persons. Of these, not less than ninety-two, or sixty-four per cent., believe in the existence of the aurora-sound, and fifty-three (thirty-six per cent.) state that they have heard it themselves, whilst the other thirty-nine cite testimonials from other people; only twenty-one (fifteen per cent.) declare that they have never heard the sound and know nothing about it, and the other thirty-one (twenty-two per cent.) have not noticed the query at all. There are thus ninety-two affirmations against twenty-one negations. The sound is variously described in these answers as sizzling, creaking, whizzing, rustling, crackling, hissing, whispering, rushing, buzzing, rippling, roaring, din, breezy, whipping, fanning, clashing, flapping, sweeping, etc.—*Nature, Sept. 24, 1885.* C.

THE DRAWING SCHOOL.

The usual closing exercises of the Drawing School were held in the Lecture room, on Thursday evening, May 13, 1886. The President, COL. CHARLES H. BANES, occupied the Chair. Addresses were made by the President, the Director and Prof. MacAllister, Superintendent of Public Schools. Numerous drawings of the pupils were on exhibition, and at the close of the addresses, diplomas were granted to students who had completed the full course of instruction. The following report of the Director, Mr. Wm. H. Thorne, was read, showing the operations of the School during the past year: (W.)

ANNUAL REPORT OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE, FOR THE SESSIONS 1885-1886.

Notwithstanding the continued depression in manufacturing, this has been an eminently successful season of the Drawing School, in number of pupils, completeness of organization and efficiency of instruction. The number of pupils has been exceeded but once in the history of the school, and that was during 1882-3, a period of exceptional activity. The most encouraging feature of the season just passed has been the large attendance during the Spring Term, which was ninety-three per cent. of that during the Winter Term. The system of instruction in MECHANICAL DRAWING has been further improved, and, for correctness and thoroughness, is believed to be unexcelled. This department is under the immediate charge of the Director, MR. WILLIAM H. THORNE, and consists of JUNIOR CLASSES, under MR. WILLIS H. GROAT, for the study of Geometrical Problems and Elementary Projections; INTERMEDIATE CLASSES, under MR. CARL BARTH, for the study of Projections, Intersections and Developments; and a SENIOR CLASS, under the Director, for Technical Drawing. The ARCHITECTURAL and FREE-HAND CLASSES, under MR. CLEMENT REMINGTON, have made rapid progress and have done excellent work in making Plans, Elevations and Details of modern cottages in the same manner as in Architects' offices, and in copying from the flat in pencil and crayon, and in drawing in crayon and painting in oil from casts. These classes have been larger and more interested than ever before.

The students of the school are to be congratulated on the opportunity which has been given them, at a nominal cost, for obtaining a good foundation in the principles and practice of constructive and artistic drawing, and, as a rule, they have taken proper advantage of it.

Among them, the following deserve HONORABLE MENTION for their attention, industry and progress:

IN THE SENIOR MECHANICAL CLASS.

Thomas B. Main,
Joseph Hagman,
Ellwood M. Rowand,
Samuel Davis,
Barclay Thorn,
John Rowland.

IN THE INTERMEDIATE CLASSES.

Thomas Stephen,
Gilbert B. Downes,
T. Edward Schiedt,
William F. Stroud,
Sören Olsen,
Albert E. Atkinson,
Edward A. Muir.

IN THE JUNIOR CLASSES.

Frank R. Vernon,
W. G. Goodwin,
Henry Spiegel,
Theodore Fisher,
Leon Lake.

IN THE ARCHITECTURAL CLASS.

Horace T. Hatton,
Joseph Trottmann,
Arthur Cryer,
H. J. Parrott,
Charles M. Williams.

IN THE FREE-HAND CLASS.

Adolph Schmid,
William H. C. Swain,
John R. Griffiths,
Edward Winkens,
William Rothfuss,
Mary H. Goudkop,
Eugene Dillon,
Arthur Taylor,
Charles Scherer,
Edward Seatier.

The following students are awarded SCHOLARSHIPS from the B. H. BARTOL fund, entitling them to free attendance during the next Term, beginning SEPTEMBER 28, 1886, when they will present themselves to the Actuary and receive their tickets:

Thomas B. Main,
Thomas Stephen,
Frank R. Vernon,
Adolph Schmid,
William H. C. Swain,
Horace T. Hatton.

The following students, having attended the school during four terms, are awarded certificates to that effect:

Ellwood M. Rowand,
John Rowland,
William C. Bolgiano,
William Hoeller,
Thomas Kirk,
Edwin J. Rooksby,
William T. McAllister,
E. Morgan Denney,
Franklin Farley,
Thomas W. Draper,
Charles M. Williams,
William Rothfuss,
Joseph Trottmann,
Minnie M. Parker,
Guido Ferrari.

Continued efforts will be made to maintain and improve the high standard of the school, and to add to the usefulness and importance of this department of the FRANKLIN INSTITUTE.

WM. H. THORNE, *Director*.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, April 21, 1886.*]

HALL OF THE INSTITUTE, April 21, 1886.

COL. CHAS. H. BANES, President, in the Chair.

Present—111 members and thirteen visitors.

Eleven persons were reported to have been elected to membership since the last meeting.

The Chairman of the Committee on Science and the Arts reported that the Committee had recommended the award of the John Scott Legacy Premium and Medal to Dr. FRANCIS V. GREENE, of Philadelphia, for his process of Extracting Oil and Albuminoid Matter from Corn, etc.; and to LUCIUS J. PHELPS, of New York, for his System of Induction Telegraphy.

It was ordered that the Committee's recommendations in the cases above named be approved; and the Secretary was directed to communicate the action of the INSTITUTE to the Committee on Minor Trusts of the Board of City Trusts.

The Special Committee on Reorganization made a lengthy report which was accepted, and the Committee continued. It was further resolved that the Committee be directed to prepare, in accordance with the present By-Laws, the necessary changes in the same in order to carry into effect the recommendations of the report; and that the Committee be requested to prepare plans for a new building, and select a suitable site for the same. It was also ordered that the Committee's report, together with the text of the proposed amendments, be printed and a copy sent to each member of the INSTITUTE.

The Secretary presented his monthly report of progress in Science and the useful Arts.

Adjourned.

WM. H. WAHL, *Secretary*.

[*Proceedings of the Stated Meeting, held Wednesday, May 19, 1886.*]

HALL OF THE INSTITUTE, May 19, 1886.

CHAS. H. BANES, President, in the Chair.

Present—144 members and four visitors.

The election of fourteen new members was reported.

Papers were read by MR. HOWARD M. DUBOIS on "Tests of Vehicle Wheels," and by MR. FRED. E. IVES, giving the results of some recent experiments on the preparation of "Color-Sensitive Plates for Photographic Purposes." Both papers, together with discussion thereon, have been referred for publication.

MR. PEDRO G. SALOM gave an oral account of the process of manufacturing castings of wrought iron and steel, called by the inventor, Mr. Peter Ostberg, of Stockholm, "Mitis" castings, and exhibited a number of specimens of the same.

Mr. Salom described the procedure to be substantially as follows:

Mr. Ostberg has made use of the well-known fact that certain alloys of metals possess a fusing temperature much lower than that of the metals composing them; and among these aluminium alloys are especially notable. In making "mitis" castings, a very small quantity, about $\frac{5}{100}$ of one per cent. of aluminium, in the form of a seven or eight per cent. aluminium alloy of cast iron, is added to the charge (about sixty pounds) of wrought iron in the crucible the moment this has been melted. The fusing point is at once lowered some 500°, and the charge, now an alloy of iron and aluminium, becomes extremely fluid and can be cast in the finest moulds, while the great difference between its temperature and its fusing point gives all the time necessary for manipulating it without danger of its solidifying. The extreme fluidity of the charge allows the ready escape of the gases, which otherwise would make a porous casting, and the result appears to be a remarkably fine, solid and tough casting of wrought iron.

The Secretary announced the death of two prominent members since last meeting, HENRY P. M. BERKENBINE and EMILE F. LOISEAU, and it was ordered that a special committee should be appointed by the President to prepare a suitable memorial of each of the deceased members.

The meeting thereupon proceeded to take action upon the report of the Committee on Reorganization, and was thereupon adjourned.

WM. H. WAHL, *Secretary.*

THE RELATIVE MERITS OF IRON AND COPPER WIRE FOR TELEGRAPH LINES.—Mr. W. H. Preece recently read a paper before the British Association, in which he discussed the results of experiments made to determine this question. His conclusions, which we give, indicate a wide market for copper:

"Copper is gradually replacing iron for aërial telegraphs, owing to its greater durability in the atmosphere; but its greater cost has led to the use of

smaller-sized wires. This can be done without detriment to the economy of the line, for the resistance of copper, as compared with iron, varies very nearly inversely as its price per ton, and hence the cost per mile remains about the same.

"It will be observed that copper shows a very decided superiority over iron, the speeds being as follows:

	Copper.	*Iron.*
Simplex working,	414	345 words per minute.
Duplex "	270	237 " " "

"It is anticipated that the superiority of copper over iron indicated by these experiments will have a beneficial and economical influence on our telegraph system, and that its extended use will enable us not only to work better, but to dispense with intermediate repeaters in many cases where, on long lines, they are now necessary.

"The most interesting point, however, in connection with these experiments is, that they apparently prove that the superiority of copper is not simply due to its smaller electrostatic capacity and resistance, but that it is more susceptible to rapid changes of electric currents than iron; for when the resistance and capacity of the copper and iron wires were equalized by the insertion of resistance coils and condensers, the speed on the former was not thereby diminished. Possibly the magnetic susceptibility of the iron is the cause of this. The magnetization of the iron acts as a kind of drag on the currents. It is well known that telephones always work better on copper than on iron wires, doubtless for the same reason.

"These experiments also show the high speed of working that is now attained by the post-office authorities with the Wheatstone automatic apparatus. The following table gives an interesting *résumé* of the different stages of the process made, and its rate of growth:

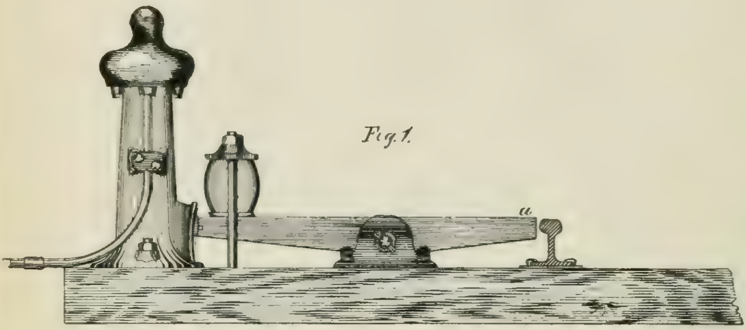
1877	80 words per minute.
1878	100 " " "
1879	130 " " "
1880	170 " " "
1881	190 " " "
1882	200 " " "
1883	250 " " "
1884	350 " " "
1885	420 " " "

—*Engineering and Mining Journal, Oct. 17, 1885.* C.

Spontaneously Reversible Lines in Spectra.—Cornu discusses various known facts, with special reference to the problem of deducing the distribution and relative intensities of the lines in the spectrum of an incandescent vapor from its chemical composition. He points out that lines which form periodic groups, are almost invariably spontaneously reversible. These lines close up toward the more refrangible end of the spectrum, and diminish in intensity. In the spectra of many metals the spontaneously reversible lines follow sensibly the same laws of distribution and intensity as the lines of hydrogen, and it would seem that this law of succession of the spectral lines, common to so many series, may possibly be expressed by the same function, which may be termed the hydrogenic function.—*Jour. Chem. Soc., Aug., 1885.* C.

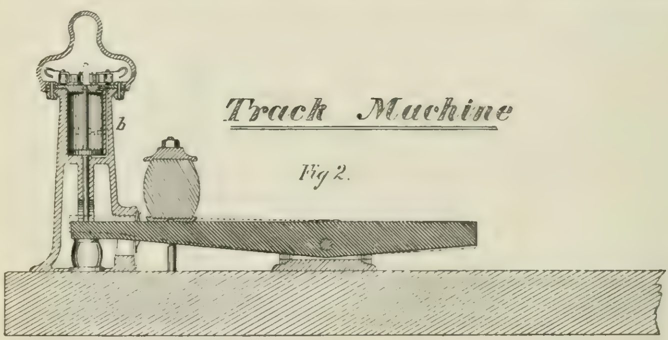
PLATE I.

Fig. 1.



Track Machine

Fig 2.



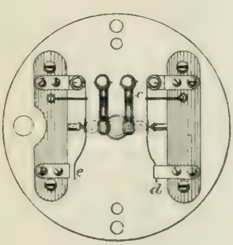
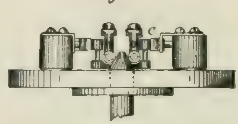


Fig 3.

Fig. 4.



1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XXII.

(SECTION IV-A, CLASSES V, VI, VII OF THE CATALOGUE.)

Electric Signaling Apparatus.
Electric Registering Apparatus,
Etc., Etc.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, JANUARY, 1886.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1886.

EDITING COMMITTEE.

PERSIFOR FRAZER, *Chairman*,

CHARLES BULLOCK,

THEO. D. RAND,

COLEMAN SELLERS,

WILLIAM H. WAHL.

1884–INTERNATIONAL ELECTRICAL EXHIBITION–1884

OF THE

FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA.
FOR THE PROMOTION OF THE MECHANIC ARTS.

Section XXII.—Railway Signals.

To the Board of Managers of the Franklin Institute:

Gentlemen:—I have the honor to transmit herewith the report of the Examiners of Section XXII on "Electric Signaling and Registering Apparatus." Respectfully, M. B. Snyder.

Chairman Board of Examiners.

Philadelphia, December, 1885.

Cambridge, Mass., September 1, 1885.

Prof. M. B. Snyder, *Chairman of the Board of Examiners.*

Dear Sir:—I hand you herewith the report of the Examining Committee in Section XXII.

Yours respectfully,

Wm. A. Rogers,

Chairman of Section.

SECTION XXII.

The Examining Committee of this Section unanimously decided that—

(1.) The Committee be divided into sub-committees, as follows:

Sub-committee I, Railway Signals, Prof. W. A. Rogers, Chairman; Messrs. Dolbear, Fiske, Kintner, Penrose, Phillips and Plush.

Sub-committee II, Time-pieces, Prof. Waldo, Chairman; Messrs. Harrington, Harkness, Kintner and Rogers.

Sub-committee III, Chronographs, Prof. Harkness, Chairman; Messrs. Harding, Kintner, Paul and Van Dyck.

Sub-committee IV, *Meteorological and other Registers*, Prof. Harrington, Chairman; Messrs. Allen, Draper, Heap, Paul and Waldo.

(2.) It was voted that, in the reports of examination of exhibits submitted to this Section, there be no direct comparison of the exhibits to the detriment of one and praise of another, but that all reports be analytical and descriptive in their nature, and point out the ascertained efficiency or inefficiency of the apparatus examined.

(3.) It was voted that all the reports of sub-committees should be signed by the examining officers and submitted to the whole section for discussion, modification and approval.

(4.) Prof. Waldo was, at his own request, excused from reporting on the exhibit of the Time Telegraph Company.

M. W. HARRINGTON,

Secretary of Ex. Com. of Sec. XXII.

REPORT OF SUB-COMMITTEE ON RAILWAY SIGNALS.

Three systems of signals were entered for examination, viz :

(1.) The system of the Union Switch and Signal Company, of Pittsburgh, Pa.

(2.) The Hall System, exhibited by the Wharton Switch and Signal Company.

(3.) The Putnam System of Audible Signals, exhibited by the Railway Cab Electric Signal Company.

The examination of these systems will proceed in the following order:

(*a.*) Statement of the fundamental principles employed.

(*b.*) Statement of the results claimed to be accomplished.

(*c.*) Description of the methods and mechanical devices employed.

(*d.*) An examination of the performance of the system in the experience of the railroads upon which it is in operation.

THE UNION SWITCH AND SIGNAL COMPANY.

(*a.*) The fundamental principle upon which this system rests is a *closed rail circuit* for a distance determined by the relation between the intensity of the current developed by the battery and the distance at which the greatest efficiency is maintained. From experience, it has been found that this distance is from one to two miles.

(*b.*) It is claimed for this system:

(1.) That the condition of the track in a given section is shown, without chance of failure, indicating also whether it is occupied by a full train, or any part of a train. Any interruption of the constant current supplied from a battery, at one end of a section and a signal magnet at the other end, displays a danger signal. These signals will be shown

(*a.*) When a train on entering a section making a metallic connection between the rails through the wheel and axle demagnetizes or shunts the signal magnet.

(*b.*) When there is a broken rail or a misplaced switch in the section, and when there is a train on a side switch not clear of the fouling point on the main line, without regard to the position of the switch.

The mechanism employed in the interlocking and block signal-
cribed as

crossing
switches,
preven-

subject
ocking"
ccidents.

ces used
ator, of a
may be
a safety

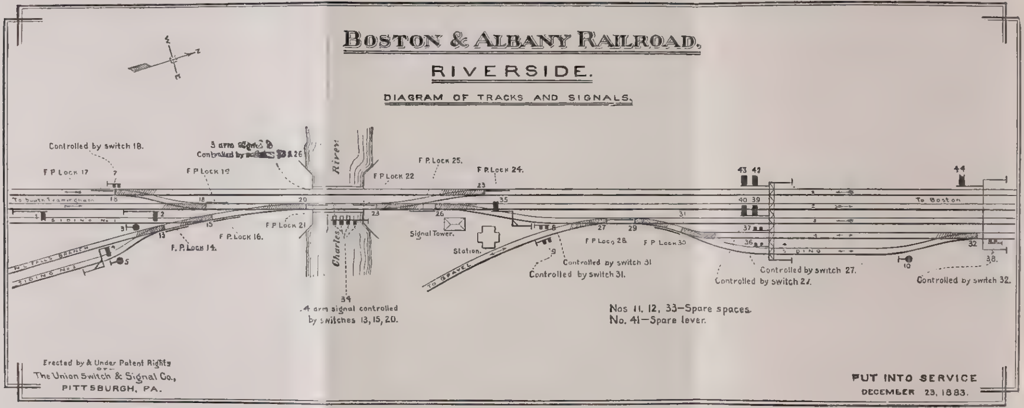
me, and
and and

is pro-
is gov-
a com-

signals
e being
moved

signals
vork, as

re pro-
witches
equired
switches must first be set and locked in their proper positions for
the train movement, which is about to be performed, before the
signals can be given to allow the train to proceed; and the clear-
ing of such signals, by the movement of their proper levers, locks



connection between the

The mechanism employed in the interlocking and block signaling systems of signals exhibited by this company are described as follows:

INTERLOCKING AND BLOCK SIGNALING.

The accidents that are constantly occurring, at grade crossing junctions, draw-bridges, and where there are numerous switches, have rendered the use of some system of appliances for the prevention of such accidents absolutely necessary.

A number of railways are now giving attention to this subject and are introducing what is known technically, as "Interlocking" and "Block Signaling Apparatus," for the prevention of accidents.

INTERLOCKING APPARATUS.

"Interlocking Apparatus" is the term applied to devices used for the movement, from a common point, by a single operator, of a number of switches and signals in safe order, so that trains may be allowed to proceed without danger, after having received a safety signal.

The best form of apparatus known up to the present time, and which has been worked to very great perfection in England and this country, is the Saxby & Farmer.

Where such apparatus is used, each switch and signal is provided with a moving mechanism, the operation of which is governed by the operator, through suitable connections, from a common point, usually termed a "Signal Cabin, or Tower."

The cut, *Fig. 1*, shows an arrangement of switches and signals where interlocking apparatus is used to advantage, there being twelve switches and thirty-one signals, which have to be moved in a certain predetermined order.

The connections (of rods or wires) from the switches and signals are attached to a system of levers arranged in a frame-work, as shown by *Fig. 2*.

This frame-work is located in the tower and the levers are provided with interlocking apparatus, so arranged, that the switches and signals can be moved only in a safe order; that is, the required switches must first be set and locked in their proper positions for the train movement, which is about to be performed, before the signals can be given to allow the train to proceed; and the clearing of such signals, by the movement of their proper levers, locks

the apparatus so that the switches cannot again be moved until the signals have been restored to the "danger" position.

The interlocking devices on the machine have been worked to such perfection that any required combination of switches and signals (for one or more trains at the same time) can be made, while the levers governing conflicting movements are absolutely locked.

This interlocking apparatus is also so constructed that even where several switches and signals are to be moved for one train operation, the movement of these switches and signals in a proper order is regulated, and this order may be in accordance with the rules of any railroad.

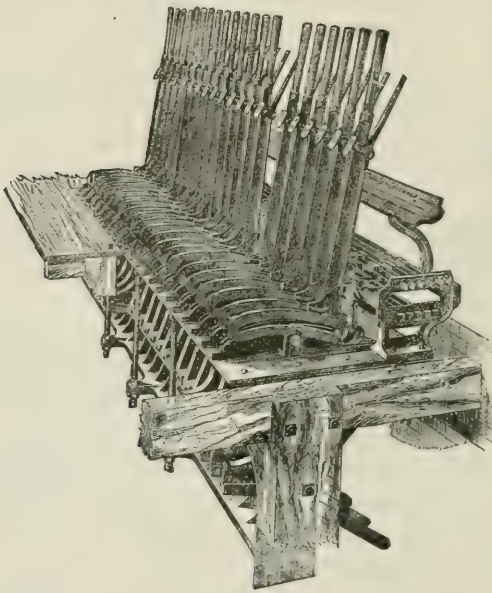


FIG. 2.

The constant use of interlocking apparatus, such as the Saxby & Farmer, and kindred appliances, has led to great perfection in every detail; such as the proper arrangement and construction of the connections from the "tower" to each switch and signal, the devices for compensating for the expansion and contraction of such connections, and the locking devices for the switches, as well as the interlocking apparatus on the machine in the tower.

From the foregoing brief statement, it will be seen that the clearing of signals for a train to proceed locks the switches over

which the train is to pass; and it necessarily follows that restoring these signals to "danger" will unlock at least one of the switches in the combination, the movement of which in turn will unlock the next switch, and so on.

In order to prevent the movement of switches under passing trains, "detector bars" are arranged in connection with the switch locking apparatus, in such a manner, that the unlocking of the switch cannot take place so long as the train is passing such bar. This "detector bar" is a piece of iron about forty-five feet in length, or of a length greater than the distance between the trucks of a car, and is hinged along the rail and connected to the lock of the switch.

The use of the detector bars became necessary in connection with switches, because of the liability of operators to move switches before the last car of the train has passed.

"Interlocking Apparatus" of the kind above described is that now commonly used on all the English railways.

But with all such appliances there has, however, been lacking some device, out of the control of the operator, which would prevent him, if confused or not being able to see clearly, from giving safety signals when the track on which the train is to pass is occupied, or obstructed by another train or car standing upon a siding in such a position as to cause a collision.

ELECTRIC LOCKING OF THE INTERLOCKING APPARATUS.

The Union Switch and Signal Company are attaching, in connection with the various interlocking apparatus, which they are manufacturing, automatic electric appliances, which absolutely prevent an operator from making a mistake; and the system by which this is accomplished is known as the "Electric Locking of the Interlocking Apparatus."

This Electric Locking Apparatus has now been used a sufficient length of time to show that it is an absolute safeguard against mistakes on the part of the operator; and the claim is made by those who have had experience with interlocking, with and without it, that interlocking apparatus may be a source of great danger, unless provided with this additional safeguard, inasmuch as in the one case, an operator may, without design, cause a serious acci-

dent, while with the electric locking he is powerless to give clear signals, except when the track is absolutely clear.

The perfect electric locking, as above described, depends upon the use of what is termed the "track circuit system." In this system, the rails of the track are utilized as electric conductors, in such a manner that, if any portion of the track or sidings to be guarded, is occupied by even a pair of wheels, the interlocking apparatus in the tower is automatically locked and kept locked until the electric current is restored to its normal channels by the removal of the obstruction.

The system of interlocking has grown, step by step, from the movement of one switch and its signal, to the movement of a number of switches and signals in complicated yards.

The various additions to the system, made as a result of experience, have led to a development of " the art," and have shown to those who have followed their introduction the various safeguards that have been needed to render the system absolutely safe.

The enormous number of patents taken out for interlocking apparatus shows that the subject has been studied in all its phases, but until the present time (with the exception of the hydraulic apparatus) the interlocking has remained of what might be termed the mechanical form; that is, an arrangement of levers, rods and wires moved by hand, as hereinbefore described.

The hydraulic system has received great attention, and has been perfected in all its details, so as to accomplish, by means of hydraulic pressure, what has been accomplished by the mechanical.

The complicated system of switches at East St. Louis, with the necessary signals, is operated by the hydraulic system, eighty-four levers arranged in a tower being capable of moving as many switches and signals as could be moved by 200 Saxby & Farmer levers.

Within the last two years several of the leading railroads of the country have put in appliances for operating switches and signals, known as the Westinghouse Pneumatic Interlocking Switch and Signal System. In this system, the experience gained in the use of compressed air for automatic railway brakes has been taken advantage of, and the working of this new system will be watched with great interest, because of the many advantages which it will possess over any other known form of interlocking. In this system,

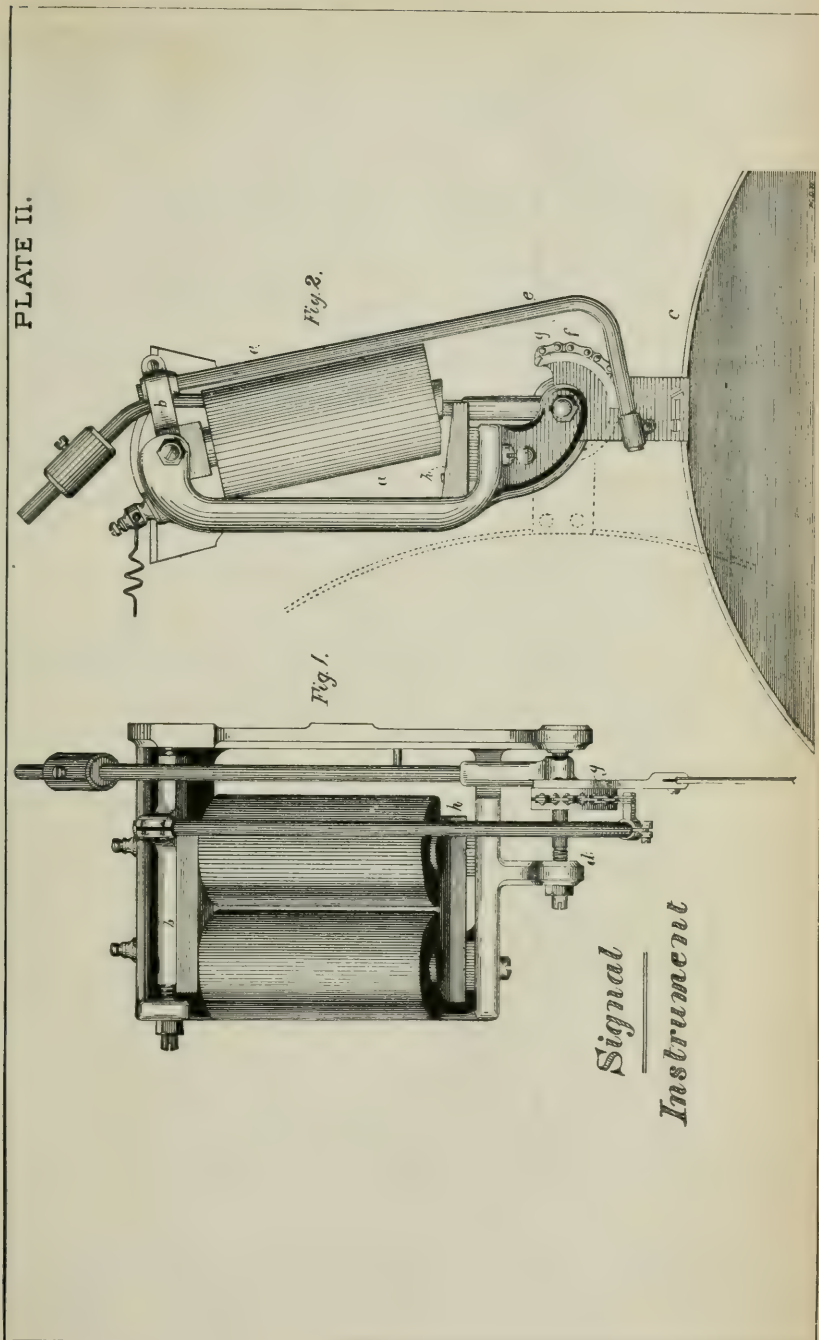


PLATE II.
Fig. 2.
Fig. 1.
Signal
Instrument

compressed air furnishes the motive-power for operating the switches, signals and locks, and electricity is used for the purpose of locking or unlocking the apparatus moved by the operator, and also for bringing the compressed air into use for the operation of signals.

By the use of electricity, it has been possible to provide locking apparatus, in connection with each switch and combined with the machine in the tower, for preventing the complete movement of a switch lever by the operator, until such switch has not only been moved to, but absolutely locked in, its proper place It has also been possible to prevent the clearing of signals until the switches have been moved and locked in their proper positions, for the clearing of the signal is made dependent upon the locking bolt being moved entirely to its seat. Also, in this new system, the clearing of the signals automatically locks the levers in the tower, and holds them locked, until the required train movement has been performed, and until the signals have been restored to their danger positions; the unlocking depending, not upon the movement of the lever in the tower for putting the signal to "danger," but upon the signal itself assuming its "normal," or danger position.

To this apparatus there is applied the "track circuit system" of locking, whereby the operator is prevented from making conflicting train movements, or giving "clear" signals, or moving switches, unless the track over which the train is to pass is clear.

By the use of compressed air as a motive-power, the labor attending the operation of switches and signals is reduced to the simple movement of miniature levers. The mechanism in the tower, for the operation of a large number of switches, is brought into a very small space, while the movement of switches and signals is rendered possible at distances which could not be attempted, were their operation to depend upon the movement of long rods or wire connections.

By the use of this system, the connections for the transmission of the power (being pipes and insulated wires), may be placed underground, so that they cannot be interfered with; but whether buried or not, they are unaffected in operation by extreme changes of temperature.

The machine in the tower, for moving the switches and signals in a prescribed order, is so constructed that changes in combi-

nation are easily effected, and a machine can be put in the tower which will be large enough for any possible addition to the number of switches and signals to be operated, without materially increasing the first cost of the apparatus; and the position of switches and signals can be changed with little expense, as compared with that necessary where the mechanical systems are used.

BLOCK SIGNALING.

"Block signals" is the term applied to a system of signals, the use of which is to prevent two trains from being upon a certain section of railroad at the same time.

These signals are moved by hand, by operators placed in suitable towers, and these operators are supposed not to give a "clear" signal for a train to proceed on a section until the train that has been admitted has passed beyond the next succeeding station, and the operator in that section has notified the first operator, by telegraph, that the section is clear.

This system is in general use on all the railways in Great Britain and many other European railways, and has been adopted to a limited extent on some of the leading railways of the United States.

The use of this system, however, has shown that it is imperfect, inasmuch as one operator can give misleading signals and thereby cause serious accidents.

To prevent mistakes on the part of the operators, a system known as the Sykes has been perfected.

THE SYKES SYSTEM OF LOCK AND BLOCK SIGNALING

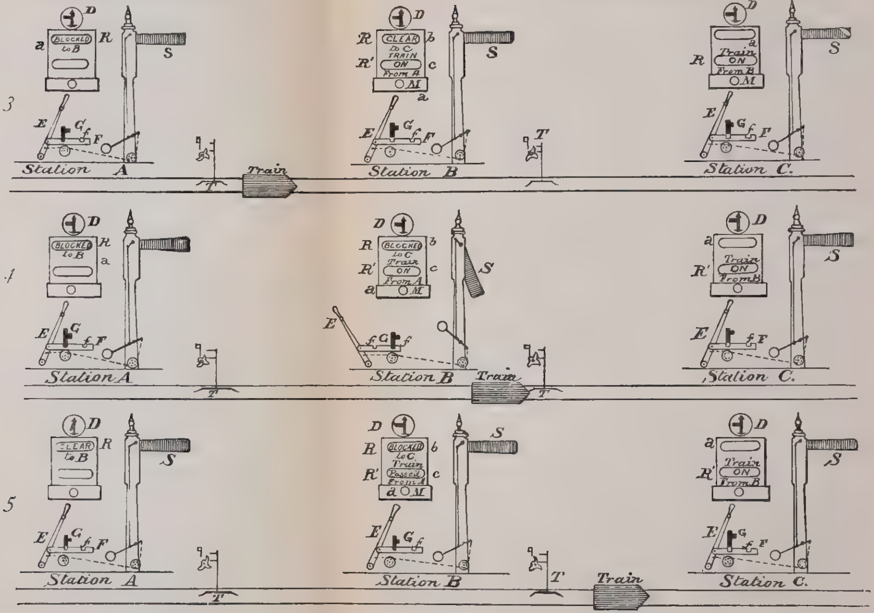
The three cuts, *3*, *4* and *5*, with the following description, will illustrate the working of this system. Each of the three cuts relate to the same three signals, as will presently be explained

The railroad is supposed to be divided into sections, at the beginning of these sections, as at *A*, *B* and *C*, is arranged a signal post having semaphore arm *S*, the normal position of which is as shown in *Fig. 3*, indicating "danger," or "stop," to a train.

Adjacent to each of these signal posts is a tower, not shown on the illustration, in which there is located a lever *E*, having a suit-

able connection leading to the signal post, whereby the semaphore

nation are easily effected and a machine



able connection leading to the signal post, whereby the semaphore arm S is operated. This lever E, carries with it a sliding bar F, having a locking device, indicated by G, capable of locking the lever E into either of two positions. In the tower is located a box a, having suitable electric and mechanical connections for operating two indicators, R and R, which are displayed through suitable openings cut in the face of the box.

In addition to the indicators in the box, is a small semaphore indicator D, placed on top of the box for indicating to the operator the position of the next signal arms S ahead. This has suitable electric connections for its operation

The indicator R reads either "clear" or "blocked," and refers to the condition of the section of track in the rear.

The indicator R is connected with the lock G in such a manner that when it reads "clear" the lock G is lifted, and the lever E is free to be moved by the operator, but when it reads "blocked," the lever E is locked.

The normal position of all the semaphore arms S is "danger;" all the levers E are "home" and unlocked; all the indicators R read "clear;" all the indicators R' read "train on;" and all the indicators D have their arms up at right angles, as shown at Station B, in *Fig 3*. A train at A being ready to start, the lever E is pulled over, thus dropping the semaphore S, after which the train may start.

The indicator R at A now reads "blocked," the indicator R', "train on," and the lever E is automatically locked. When the train passes the track treadle T, the lever at A is unlocked, and may now be returned "home" by the signal man, when it will again be automatically locked. The parts are now in the positions shown in stations A, B and C, in *Fig. 3*. When the train approaches Station B, the signal man there (having previously been notified by telegraph of the approach of a train) pulls over his lever E, and drops his semaphore S, that the train may pass. This motion changes his indicators in the same manner as at A, and locks his lever E in its "clear" position. The parts are now as shown at stations A, B and C, in *Fig. 4*. Meanwhile the lever at A remains locked; and to unlock it, the operator at B must press in the knot or plunger indicated at M, which is arranged on the front of his indicator case; but this he cannot do until his

lever has been unlocked and returned to its "home" or normal position. When the train passes the treadle T, of block B, the indicator R shifts to "clear," and the lever E is unlocked, and then may be returned "home." This act sets the indicator R to "blocked" again, locks the lever E, and sets the indicator R' to "train passed;" it also sends an electric current through the indicator D, at station A, in such a manner that its arm drops to indicate that the section between A and B is "clear." The parts are now as shown at station A, B and C, in *Fig. 5*. The operator at B may now unlock A's lever for another train, this he does by pressing in the plunger M, which sends an electric current to block A, unlocks the lever E, shifts the indicator R at station A to "clear," and causes the arm of indicator D at B to fall "clear." When B presses the plunger M and it springs back, his indicator R' shifts to "train on" (meaning that the section from A to B is in condition to receive a train), and it is then locked, so that the plunger cannot be worked again until the lever E has been pulled over and returned; and the lever E remains locked until the train has passed the treadle T at station C and the operator has pressed his plunger M.

Should another train approach B from A before the operator at C has thus unlocked the lever E at B, the semaphore S at B cannot be lowered (even should he attempt to do so), and the train must stop until the lever is unlocked by the operator at C. Thus, it is evident that it is not possible for one train to approach nearer to another than the distance between two signal stations.

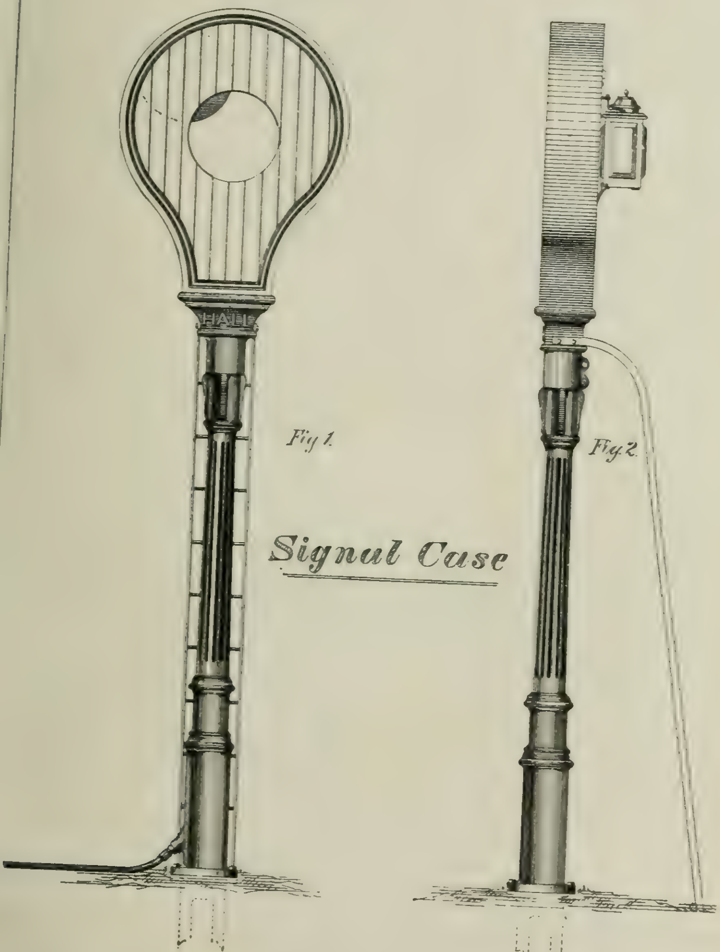
It will be seen that in this system is an absolute safeguard against operators giving wrong or misleading signals, and accidents will be prevented, unless the trainmen wilfully disobey the signals which are displayed for their protection.

AUTOMATIC BLOCK SIGNALS.

It often happens that trains are required to run much closer together than the distance between the telegraph stations on railroads, and in such cases it is important to establish an automatic system of block signals, which will provide for shorter blocks and prevent two trains from being on the same block at the same time.

Automatic signals of this kind have been experimented with and tried by a number of the leading railways in the States.

PLATE III



Signal Case

"The Rail Circuit System" seems to be the only automatic system that fully meets all of the requirements.

In this system, the line of track is divided into block sections, of a mile or less in length, and the rails of each of these sections are prevented from electrically joining the rails of the next section

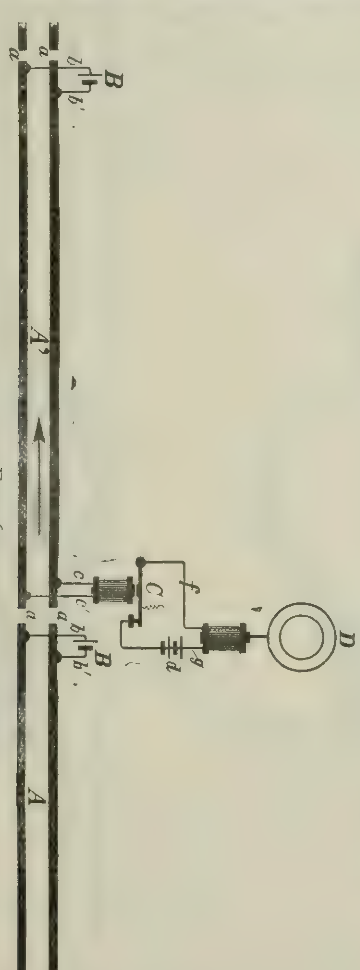


FIG. 6.

by the use of non-conducting material, suitably placed at the junction of the two sections. The rails of each block section are electrically joined one with the other, by means of wires, which are attached to rivets and driven into the flanges of the rails, near their ends. Referring to *Fig. 6*, the two broad lines represent the lines

of rail (of one track of a double track road). The track insulations between this and the adjacent sections are indicated by *a*. The battery *B*, has one pole connected by wire *b* to one rail and its opposite pole by wire *b′* connected to the other rail. At the beginning of the section is arranged an electro-magnet *C*, having one wire *c* connected to one rail and its second wire *c′* connected to the opposite rail; thus establishing an electric circuit from the battery, through wire *b′*, through one rail, through wire *c*, through magnet *C* and the wire *c′* to the other rail, and then by wire *b* to the battery.

This electric circuit is known as a constantly closed circuit, and

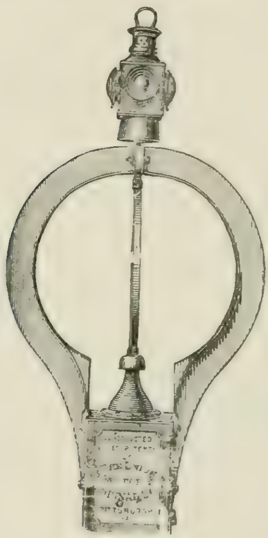


Fig. 7. "C" Signal Open.

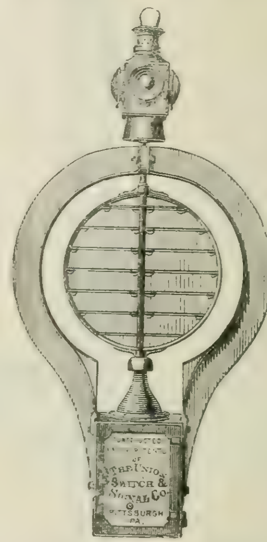


Fig. 8. "C" Signal Closed.

unless the electric current is interrupted, the armature of the magnet *C* is held to its seat, and establishes a second electric circuit through the magnet of the signal mechanism *D*, from the battery *d* by wires *g* and *f*. If the current through magnet *C* is interrupted, the armature of the magnet *C* is drawn from its seat by a spring, or is arranged to fall from its seat by gravity, in such a manner as to interrupt the circuit from the battery *d*, causing the signal *D* to turn to the position indicating "danger," restoring the circuit from the battery *d*, restores the signal *D* to its safety position.

Figs. 7 and *8* show the form of signal *D*. The electric mechanism is contained in the box at the lower part, which causes a disk to

be turned, in *Fig. 8*, to indicate "danger" and as shown in *Fig. 7* to indicate "clear."

The clock work and the weight furnishes the motive-power for turning the signal, and the electric current, through the magnet of

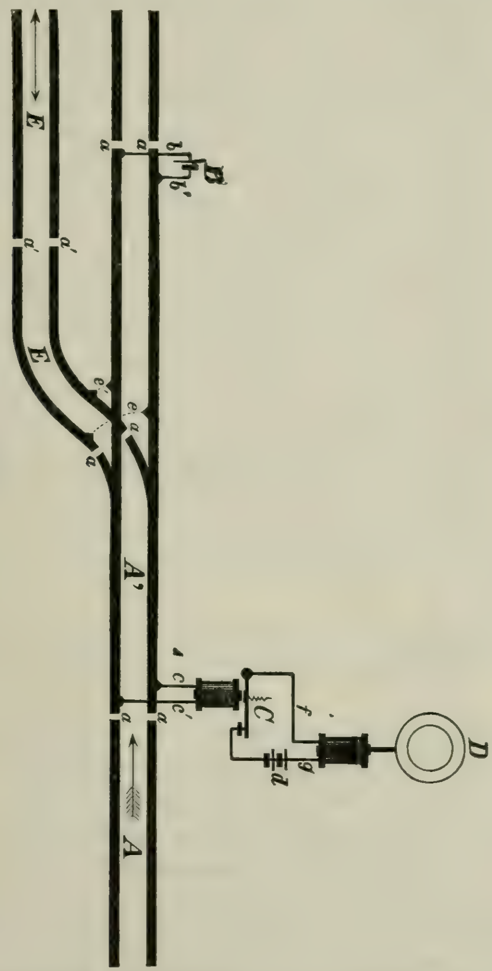


FIG. 9.

D, releases the proper mechanism for the operation of the signal. So long as the current passes through the magnet at *D*, the signal will stand to "clear," as in *Fig. 7;* any interruption of the current will cause the mechanism in the box to so operate as to turn the signal into position shown in *Fig. 8*, to indicate "danger."

From this description, it will readily be seen that if a wire from the battery B to the rail be broken, or if a rail be removed or broken, so as to interrupt the electric current, the signal D will instantly turn to "danger."

Similarly the signal is turned to danger by a pair of wheels joining the two rails of the section, for a pair of wheels and its axle has the effect of forming a "short circuit," so that the electricity, instead of passing from the battery B through the magnet C, passes to the wheel on one side, through the axle and wheel to the other rail back to the battery, which has the effect of releasing the armature of the magnet C, thereby turning the signal D to danger, the same as if a rail had been removed or broken.

Fig. 9 shows an arrangement of signals on a section, having a switch or branch. Part of the siding E is insulated at a', the same as the main track. The rails of the main section A' and the branch E are joined by wires e, e', in such a manner that a pair of wheels entering upon the branch E has the same effect as entering upon the main line; that is, to "short circuit" the current from the battery B, in such a manner as to turn the signal D to "danger." The insulations a' in the branch E are placed at a point a sufficient distance from the main track to insure a "danger" signal being given if a car or an engine stands too close to the main line upon the siding.

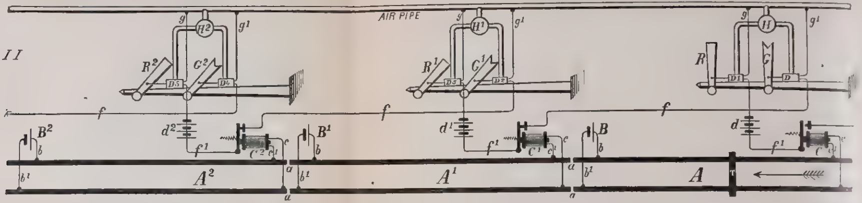
These two cuts and the description illustrate the principle of operation of the constantly closed "rail circuit system" of block signals.

Fig. 10, shows three such signals, with each signal, D, D^1 and D^2, placed a sufficient distance from the beginning of each section to enable a train to stop, after having discovered the signal at danger before it arrives at the beginning of the section.

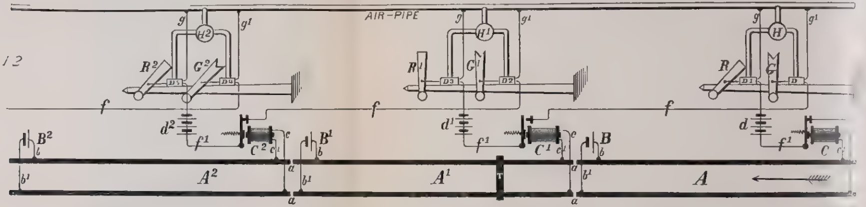
This rail circuit system has been used in connection with an infinite variety of electric signals; that is, the local circuit with its battery d, has been used for turning single signals, double signals, signals for the protection of single tracks, for locking the levers of interlocking apparatus, locking draw-bridges, locking switches, moving automatic signals, ringing of bells for highway crossings, alarm bells for depots to announce the approach of trains, etc., etc.

The essential and important feature of this system is that the failure of the battery, or wire, or any interruption whatever of the current instantly causes the signals to be turned to danger.

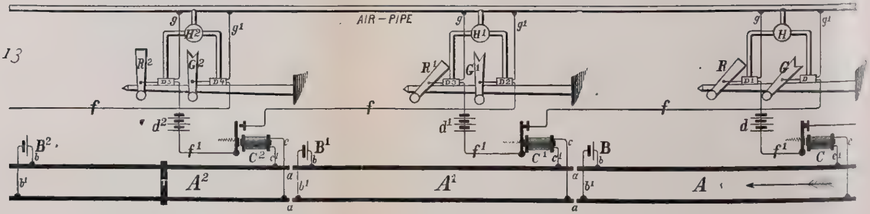
11


AIR PIPE
g
g1
H2
H1
H
R2
G2
R1
G1
R
G
D5
D4
D3
D2
D1
D
f
d2
d1
d
f1
C2
C1
C
c
c1
B2
B1
B
b
b1
A2
A1
A
a
T

12


AIR-PIPE
g
g1
H2
H1
H
R2
G2
R1
G1
R
G
D5
D4
D3
D2
D1
D
f
d2
d1
d
f1
C2
C1
C
c
c1
B2
B1
B
b
b1
A2
A1
A
a
T

13


AIR-PIPE
g
g1
H2
H1
H
R2
G2
R1
G1
R
G
D5
D4
D3
D2
D1
D
f
d2
d1
d
f1
C2
C1
C
c
c1
B2
B1
B
b
b1
A2
A1
A
a
T

Several of the important roads of the country have applied this automatic rail circuit in connection with semaphore signals, having laid a compressed air main along the track where the block signals are to be operated, the compressed air furnishing the motive-power for the operation of the semaphores. Two signals are arranged for each section, one "home" and one "distant" signal.

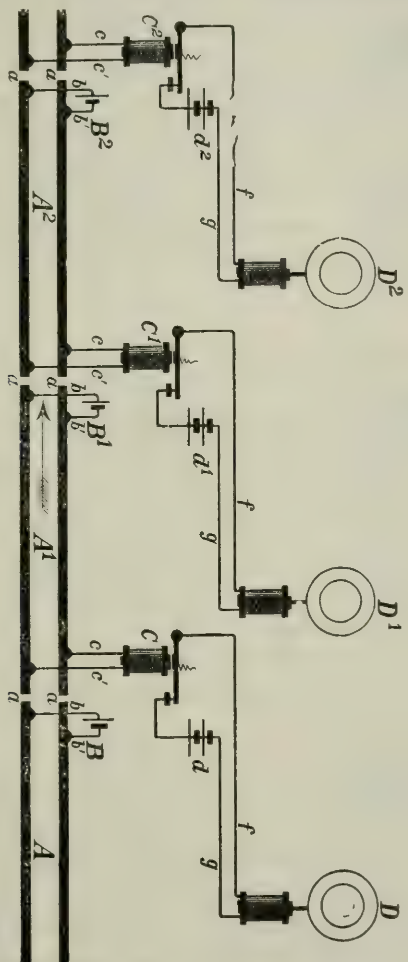


FIG. 10.

Figs. 11, 12 and *13*, illustrate the arrangement of signals.

In *Fig. 11*, a train is supposed to be on section *A*, and the two semaphore signals *R* and *G* stand to indicate "danger."

In *Fig. 12*, a train is supposed to have reached and passed on to

section A^1, turning the signals R^1 and G^1 to "danger," and at the same time turning signal R to "clear," leaving G at "danger," to indicate to an approaching train that the next section ahead is occupied by a train.

Fig. 13 shows a train on section A^2. Signals R and R^1 and G are "clear," G^1 remaining at "danger," to caution the engineer of the approaching train on section A^1 that section A^2 is occupied.

In the operation of these signals, if the engineer finds both signals clear, he can proceed at his usual rate of speed. If he finds G, G^1 or G^2 at "danger," he must be prepared to stop before arriving at the next signal post ahead, and he must not pass the next signal post ahead until one or both signals are clear. If one only is cleared, he must still proceed with caution and be prepared to stop before arriving at the next signal, in the event of both being at "danger."

METHOD OF CONTROLLING A HIGHWAY CROSSING BELL ON A SINGLE TRACK RAILROAD. SCOTT'S PATENT.

Figs. 14, 15, 16, 17 and *18* show the arrangement for giving an audible alarm of the approach of a train, at a highway crossing or other point on a single track railroad.

Fig. 14 shows the crossing A, and insulated sections R^1 and R^2, with the relay magnets c, d, connected to them, and the batteries a, a^1, for feeding the same, placed at the end of the sections farthest from the crossing.

Fig. 15 shows the relay on an enlarged scale, and also the manner of connecting the local circuit with the continuous ringing bell v.

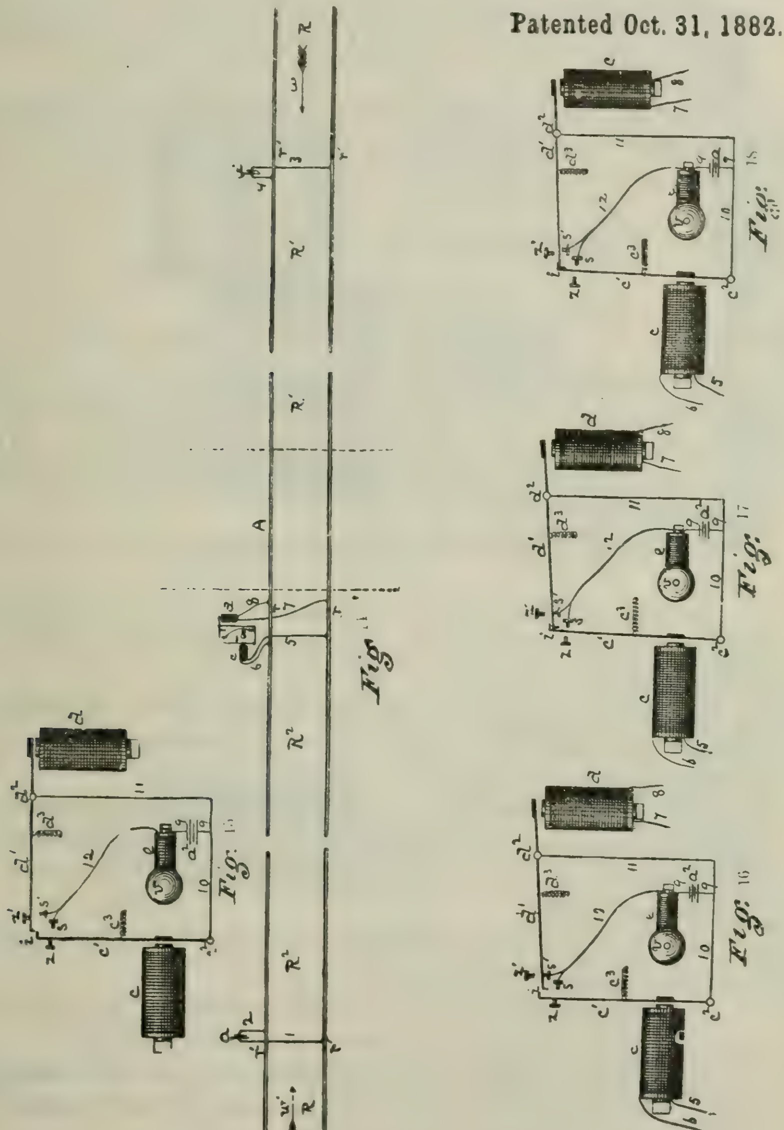
On a train approaching the crossing from the right, as indicated by the arrow w, the battery a^1 will be short circuited from magnet d, by the wheels of the train as soon as they have passed the insulations r^1, thereby demagnetizing magnet d, and its armature lever d^1, will assume the position shown in *Fig. 16*, closing the circuit of battery a^2 upon belt v, causing it to ring.

When the first wheels of the train have passed the insulations r, battery a, is short circuited, demagnetizing magnet c, and its armature lever c^1 will assume the position shown in *Fig. 17*.

When all the wheels have passed off of section R^1, battery a^1 will be restored to magnet d, magnetizing it and causing it to attract its armature.

Armature lever d^1, will then be in the position shown in *Fig. 18*, and the bell circuit will be broken as shown at s^1, and the bell will cease to ring.

Patented Oct. 31, 1882.



The train passing from the insulated section R^2, battery a, is restored to magnet c, and the apparatus resumes the position shown in *Fig. 15*.

Should a train follow the first train, and pass insulations at battery a^1, before the first train has passed battery a, the magnet d, will again be demagnetized, and the bell circuit closed as shown in *Fig. 17*.

If a train approaches the crossing from the left, as indicated by the arrow w', exactly the same operations will take place, but in reverse order.

THE HALL SYSTEM.

FUNDAMENTAL PRINCIPLES INVOLVED.

(1.) Automatic opening of an electric circuit, which holds a given signal at "safety" by the action of a passing train, the wheels of which operate a lever placed at right angles to the track. This lever raises a vertical spindle and thereby breaks the circuit in the track machine.

(2.) A gravity movement of a danger signal, when the circuit is broken.

(3.) The introduction of a relay into the circuit, by which the action of gravity will display a danger signal when the wires are either crossed or grounded.

(4.) The introduction of an interlocking device, by which a danger signal can only be set at "safety" by setting the next succeeding signal at "danger."

(5.) The introduction of a general interlocking system, by which an operator at a crossing station has the power to clear a given signal and at the same time loses the power to control all conflicting signals.

(6.) The introduction of suitable mechanism, by which a station agent has control over all signals.

(7.) The introduction of a suitable mechanism, by which the movement of a switch controls the movement of a signal.

(8.) The introduction of suitable mechanism, by which notification of the approaching trains may be given to station agents, to gate tenders, or to the general public.

PLATE IV.

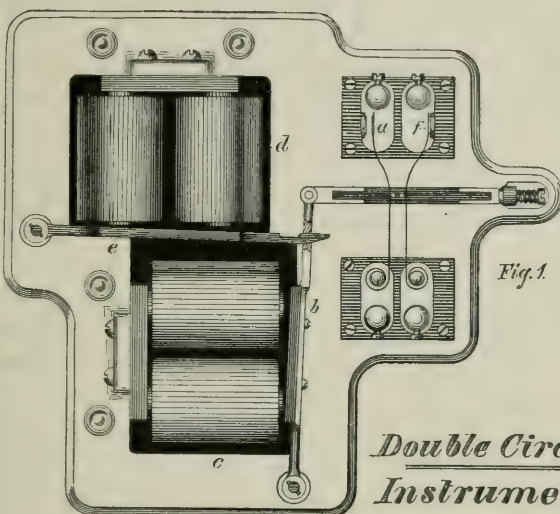


Fig. 1.

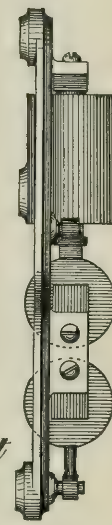


Fig. 2.

Double Circuit Instrument

Relay

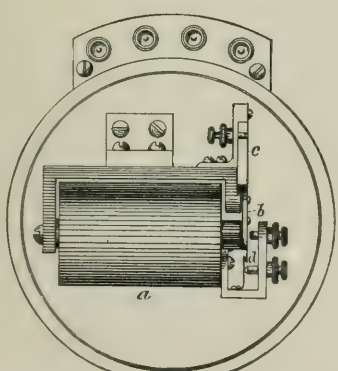


Fig. 3.

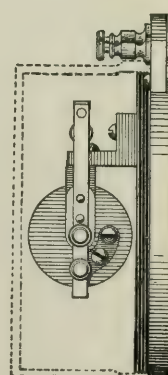


Fig. 4.

The methods by which the objects stated above are accomplished in this system, and the mechanism employed, will appear from the following description:

Plate I, Figs. 1, 2, 3 and *4* are views of the track machine, as placed at right angles to the track, used for the purpose of automatically opening an electric circuit, which holds a given signal at "safety;" by the action of the wheels of a passing train, which operate the lever at *a*, *Fig. 1*, causing a vertical piston, shown at *b*, *Fig. 2*, to be raised, so that it acts upon a lever *c*, *Figs. 3* and *4*, which breaks the circuit in the machine at *d*. A circuit may also be closed by this machine, by forming the circuit closer, as at *e*, *Fig. 3*, so that when the piston is raised by the lever, the circuit will be closed at *e*.

Plate II, *Fig. 1*, is a side view, and *Fig. 2*, a front view of the signal instrument, the gravity movement of which produces a danger signal, when the circuit is broken, referring to the drawing *a*, is an electro-magnet supported axially on a shaft *b*; *c* is a signal disc, supported axially on a shaft *d*, shown at *Fig. 1*; the two shafts are connected by means of a rod *e*, and chain *f*, the chain passing over the periphery of a sector of a circle, which forms part of the disc, as shown at *g*. The weight of the disc maintains the electro-magnet at an angle, as shown in *Fig. 2*.

The armature of the electro-magnet at *h*, is stationary; when a current of electricity is passing through the magnet, it is attracted to its armature, carrying with it the rod *e*, which turns the disc on its axis to a position at right angles to its normal condition, as shown by the dotted lines; as long as the current is maintained through the magnet, the signal will occupy this position, which indicates safety. When no current is passing through the magnet, the weight of the signal changes its position to the one indicating danger. This instrument is placed in a case, two views of which are shown in *Plate III*, *Figs. 1* and *2*.

Plate IV, *Fig. 1*, is a front, and *Fig. 2*, a side view of the double circuit instrument, which is introduced into the circuit for the purpose of continuing the action or effect produced momentarily in the track machine, and also by which the interlocking arrangement is accomplished whereby a danger signal cannot be set at "safety" unless the next succeeding signal is at "danger."

In the drawings, *a* represents a circuit closer, which is closed by

the attraction of the armature *b*, to its magnet, *c*; when this circuit has been closed it actuates magnet *d*, causing its armature, *e*, to be attracted, the act of which locks the first armature, *b*, thereby holding circuit closed at *a*; of course, if the circuit actuating magnet *d* is broken, the armature *b* will be unlocked, and the circuit will be broken at *a*; *f* is a circuit closer which acts directly opposite to *a*; that is, the closing of *a*, by means of armature *b* will open *b* and *f*, and when *a* is open, *f* will be closed.

Plate IV, *Figs. 3* and *4*, are front and side views of the relay instrument, which is introduced into the circuit, and by means of which the signal will show danger when the wires are either crossed or grounded; *a* is an electro-magnet and its armature, *b*, is mounted upon an adjustable spring, *c*, the lower end of which forms a circuit closer; when the current is passing through the magnet, *a*, a secondary circuit, which is a shunt circuit, causes the main circuit to be shunted from the signal so long as the magnet is active.

Plate V, *Fig. 1*, is a front view of the interlocking instrument, *a*, *a*, *a*, *a* and *b*, *b*, *b*, *b* are circuit controlling springs, which are operated by means of armature *c*; that is, when armature *c* is attracted, the front contact springs *a*, *a*, *a*, *a* are closed and the back contact springs *b*, *b*, *b*, *b* are opened; when the armature has been so attracted it is locked by means of a detent, *e*, on armature *g*, and must so remain until the armature *g* has been attracted. This operation of course will withdraw the detent and cause the armature, *c*, to return to its normal condition, which opens the front and closes the back contact springs. Any desired number of springs can be used, as the case requires.

In *Plate VI*, are five figures representing the switch machine, by means of which the movement of the switch controls the signals. *Fig. 1* is a side view of the machine as placed at right angles to the track, and attached to the switch rail as shown at *a*. The movement of the switch rail from the main line of track, in either direction, would cause the lever *b*, shown in *Fig. 2*, to swing on its fulcrum, as indicated in the dotted lines. The short arm of the lever carries a small roller, *c*, which runs over a spring, as shown in *Figs. 4*, *5*, and *6*. This spring has indentations so formed in it, that it will open or close as the roller passes over it, according to the form of the spring.

In this manner, circuits are automatically broken or closed by the movement of the switch, as the case may require. In *Fig. 4*, the switch being on the main line, the roller would stand in the centre of the spring, and thereby the circuit would remain closed, but if the switch was moved in either direction the spring would open, as shown at *d* and *e*. In the case of *Fig. 5* it is the reverse; the circuit is open when the switch is on the main line, and closed when moved in either direction from the main line.

By referring to *Plate VIII*, *Fig 2*, *O* represents a board upon which is placed two bells, two circuit breaking and two circuit closing keys. By means of these keys, the station agent may manipulate the signals as may be required. The operation of the bells give notification of the condition of the signals.

For the purpose of giving notifications to gatemen at crossings, and to the public waiting at stations, of the approach of trains, striking bells are used, which are operated automatically by the passage of the train at a given point distant from the station or crossing.

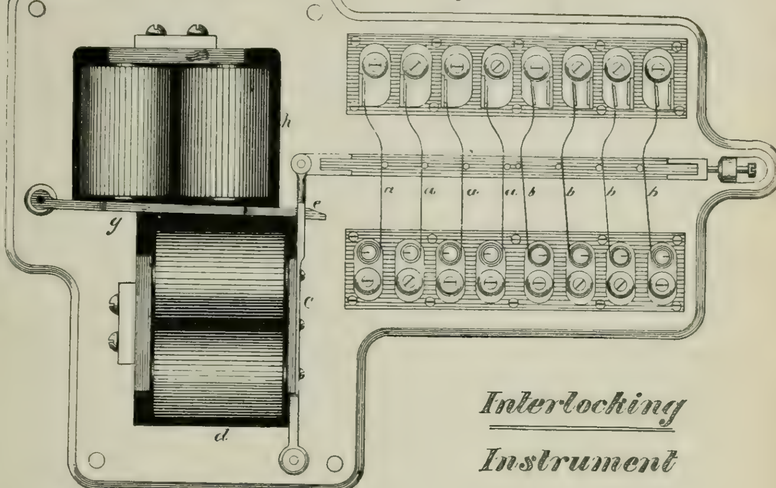
At highway crossings, where no gates are used, a large vibrating bell, shown in *Fig. 1*, *Plate VII*, is placed in a case, shown in *Plate VII*, *Figs. 2* and *3*, and erected at the crossing, so that when the train is approaching and when within one-half mile, more or less, from the crossing, the bell is automatically put in operation by the train, and continues to ring until the train passes the crossing. The remaining three plates consist of diagrams showing the application of the above described instruments. The general operation of the block signals will be understood by the explanation of *Fig. 1*, *Plate VIII*. *A*, *A* is a portion of track upon which trains run in the direction indicated by the arrow. This portion of track is divided into three sections, each of which is protected by a signal, as shown at Nos. 1, 2 and 3; a, a', a'' are double circuit instruments, b, b', b'' are relay instruments; c, c', c'' are track instruments, which are placed about 1,500 feet beyond the signals. The conditions of the signals when no trains are occupying the track, are at safety; they are maintained in this condition, as will be seen by tracing the circuit of No. 1 signal; commencing at battery X, the circuit runs by wire 1, through magnet d, wire 2, circuit closer e, wire 3, electro magnet f, wire 4, circuit breaker g, on track instrument c, wire 5, to the ground; this circuit being complete, the Signal No. 1 will

remain at " safety." The same circuit exists at each signal. When the train passes into the section protected by the signal, and operates the track instrument *c*, it will momentarily break the circuit above traced, and the signal will fall by gravitation to danger; at the same time the magnet *d* will be demagnetized, and its armature will release the armature of magnet *h*, causing the circuit to be permanently broken at *e*. This circuit can only be restored again by magnet *h*; when this magnet is vitalized, it will again close spring *e*, and the circuit through the signal will be complete, so that it will be set to safety. The restoration of this signal takes place after the train has passed into the section protected by Signal No. 2. In track instrument *c*, is a circuit *breaker* and a circuit *closer*, the circuit breaker is in circuit with Signal No. 2, exactly as described in No. 1. The circuit closer is in circuit with magnet *h*, on instrument *a*; it also includes magnet *i*, in relay *b*. By tracing the circuit, we find it runs from battery *x*, by wire 2, through magnet *i*, wire 6, magnet *h*, wire 7, spring *k*, wire 8, circuit closer *l*, on track instrument *c'*, to the ground. If the spring *k* is closed, the train operating track instrument *c'* will vitalize magnet *h* and *i*, on instrument *a* and *b*, which will restore spring *e*, and cause Signal No. 1 to be set at safety. So long as the train is operating track instrument *c'*, the circuit will be maintained so that *i* will shut the circuit from the signal, as follows: From battery *x*, through wire 1, magnet *d*, spring *e*, wire 9, circuit closer *m*, wire 10, to the ground. After the last wheels of the train have left the track instrument, the shunt circuit will be opened by the demagnetizing of magnet *i*, and the signal will be set to " safety." It will readily be seen that it is impossible to set Signal No. 1 to " safety" unless Signal No. 2 is at "danger," because so long as Signal No. 2 is at "safety," the back contact spring *k* will be open, and the restoring circuit running through it will be broken. If, from any cause, the wires should become crossed or grounded, the relay magnet would be actuated, shunting the circuit from the signal.

In *Fig. 2*, *Plate VIII*, is a station block application. The operation of which will be understood by the following explanation. As a train approaches the station towards Signal No. 1, the operation will be as follows: Upon reaching track instrument *a*, it will close a circuit through wire No. 1, bell *b*, to battery *V*, thereby operating the bell (which has been placed on the side of the station for

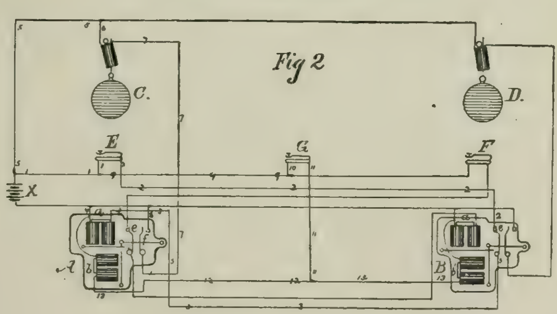
PLATE V.

Fig. 1.



Interlocking Instrument

Principle of Interlocking.



the purpose of giving notification to passengers); having reached track instrument *c*, it breaks the signal circuit, which runs as follows: From the ground through the magnet of Signal No. 1, wire 2, circuit breaker *d*, wire 3 (which passes through circuit breaker on switch instrument *e*), wire 4, circuit breaker *f* on station agent's board *O*, wire 5, wire 6, front contact spring *g*, magnet *h*, wire 7, to battery *W*. This causes the signal to fall to "danger," and the circuit will be permanently broken, as before described. The act of setting the signal to danger causes the back contact spring *i* to close, which completes a circuit from battery *x*, through wire 8, contact spring *i*, wire 9, and small bell, on station agent's board; causing the bell to ring as long as the signal is at "danger," thus notifying him at all times of the condition of the signal. The train, on passing track instrument *j*, completes a circuit through wire 10, relay magnet *k*, wire 11, magnet *l*, to battery *W*, and thereby restoring the signal circuit.

If the switch be misplaced, the signal circuit is broken, and cannot be restored as long as the switch remains open; in the same manner, the station agent can break the circuit by means of his key *f*, and as by *n* is a branch from the restoring circuit, he can restore the signal, provided the circuit has not been broken at any other point.

On the other side of the station, the arrangements of signals, circuits, etc., are similar to those already described, with the exception of the application for the side track, used for the purpose of shunting passenger and freight trains, which accomplishes the following operation: After a freight train has taken the siding and returned the switch *p*, to the main line, it closes a circuit, by means of track instrument *r*, which restores the signal to safety; as the passenger train approaches the station, it will, in addition to ringing the regular bell at the station, operate magnet *s*, in instrument *D* (as the circuit runs through the magnet on its way to the bell *b′*), the operation of this magnet will close spring *u*, which completes the circuit to small bell *E* (placed in close proximity to the switch).

This being an interlocking instrument, the spring will remain closed and the bell will continue to ring until the train passes track instrument *V*, when it restores the signal; the restoring circuit, running through magnet *w*, unlocks the spring and the bell circuit is broken; by this means the engineer of the freight train knows

that so long as the bell continues to ring, there is a train in the section; when the freight train leaves the siding, the danger signal is set by the opening of the switch, and it will be restored upon the train's leaving the section at *V*.

The operation of the interlocking will be understood by first referring to *Plate III, Fig. 2*. This figure represents the principle upon which the interlocking is based. *A* and *B* are interlocking instruments. *C* and *D* are their respective signal instruments, their normal condition being at "danger." *E* and *F* are circuit closers, corresponding to the signals, and by means of which they are operated. *G* is a circuit closer for restoring the signals to danger after they have been operated. With this arrangement in its normal condition, it is possible to operate either one of the signals by means of its corresponding key, but the act of operating one signal makes it utterly impossible for the operator to clear the other signal, until the first has been restored. This is accomplished in the following manner: The circuit from key *E* to operate signal *C*, runs as follows: From battery *x*, through wire No. 1, circuit closer *E*, wire 2, front contact spring on instrument *B*, wire 3, magnet *a*, wire 4, to the battery. The circuit from key *F* runs in the same manner through front contact spring on instrument *A*; therefore, if we close the circuit at *E*, we operate magnet *a*, which opens front contact spring *e*, on instrument *A*, and close back contact spring *f*; the closing of this spring completes a circuit from battery *x*, through wire 5, wire 6, signal magnet *c*, wire 7, spring *f*, wire 8, to the battery, causing signal *c* to raise to "safety;" it will now be seen that if we depress key *F*, the circuit will be broken at *e*, in instrument *A*, so that it will be impossible to affect the corresponding instrument. In the same way, if key *F* has been closed first, it breaks the circuit of key *E*. After a signal has been set or cleared, it can be restored at *g*; when this key is depressed, a circuit is completed from battery *x*, through wire 1, 9 and 10, 11, 12 and 13, to the restoring magnets *b* and b^1, which raise the springs. This principle can be largely extended by increasing the number of springs on the instruments. An example will be given of a practical application of the principle to the crossing of two single track roads at grade, shown in *Plate IX*.

A, *B* represent the two roads, crossing each other; in close proximity to the junction is a cabin, or tower, in which a case is

placed, containing the apparatus, by means of which the operator controls the movements of the trains. About one mile from the junction are placed track instruments, a', a'', a''', a; about one-half mile from the junction are placed signals, Nos. 1, 2, 3 and 4. The normal condition of which are at "danger;" in close proximity to them are track instruments, b, b, b, b. If, for example, a train is approaching the crossing towards Signal No. 1, reaching track instrument a, it closes a circuit through the wire No. 1, to a small indicator drop, through its magnet to wire 20, and thence to the battery, this causes the indicator to display a number, corresponding to the signal towards which the train is approaching, which in this case is No. 1. The dropping of this indicator closes as secondary circuit, which can be traced from battery O, through wire 2, small bell c, wire 3, indicator 1, wire 4, to the ground. The operator is thereby notified, by the bell, of the approach of a train, the indicator designating the track occupied by the train.

The operator must therefore clear Signal No. 1 to allow the incoming train to enter the protected section. He then depresses key No 1, closing a circuit through wire 5, front contact spring on interlocking instrument, No. 4, wire 6, spring on instrument No. 3, wire No. 7, spring on instrument No. 2, wire 8, to unlocking magnet on instrument No. 1, thereby unlocking the few front contact springs and closing the two back contact springs on that instrument. It will be discovered, by tracing the circuits from the remaining three keys, 2, 3 and 4, that they all run through the front contact spring on this instrument, before they go to the magnets on their respective instruments, consequently the unlocking of this instrument has cut away from the system these three keys, so that it is impossible to obtain any result from them, or to clear the Signals Nos. 2, 3 and 4, which operation, were it possible, would permit conflicting trains to have the right of way, the unlocking of this instrument closes the two front springs, the first of which closes a circuit from battery P, through wire No. 9, front contact spring in instrument No. 5, wire No. 10, through a miniature signal instrument (in the operator's case) wire No. 11 to Signal No. 1, thereby causing the signal to be set at safety. The miniature signal is used as a tell-tale to repeat, before the operator, the movements of the outside signal, and in this case shows him he has cleared the Signal No. 1. The train, upon reaching track instru-

ment *b*, closes a circuit through circuit closer *c*, which completes a circuit through wire No. 12, spring No. 2, in instrument No. 1 (which is now closed) wire No. 13, to the unlocking magnet on instrument No. 5. This opens the front contact springs and closes the back contact spring on this instrument, as the signal circuit ran through one of these front springs, it will, of course, now be broken so that the signal will drop to "danger," to protect the train in the rear. (It will be understood that the remaining keys cannot be operated.) The closing of the front spring in the the last instrument completes a circuit to a miniature signal marked *L B*, which indicates Line Blocked. Thus the operator is notified that the train is still in the section. Reaching track instrument *b′*, the train completes a circuit through spring *F*, wire 14, front spring on instrument No. 2, wire No. 15, locking magnet in instrument No. 1, wire No. 16, locking magnet in instrument No. 5, wire No. 17, to wire No. 40, thence to the battery, thus restoring the system to its normal condition, this being indicated to the operator by the return of the Line Blocked indicator to Line Clear, caused by the restoring of instrument No. 5, which breaks the circuit by the back spring. The same results are produced as trains approach on either of the other tracks.

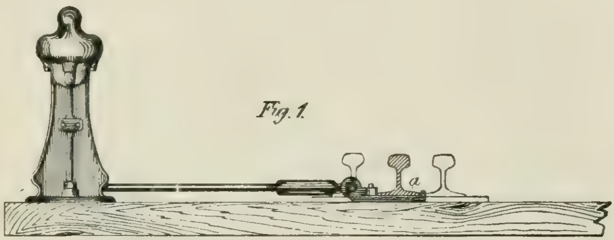
A prominent feature of this interlocking arrangement is the cutting out of track instruments; that is, train operating track instrument *b*, has no effect on one of the circuit closers, the one that restores the system when a train comes from the opposite direction. In other words, a train uses only such circuits as are necessary to work its signals in one direction.

In *Plate X*, are two diagrams representing applications of a continuous ringing bell at highway crossings, one being a double and the other a single track arrangement.

In *Fig. 1*, a train approaching the crossing in the direction of the arrow No. 2 will break a circuit at track instrument *a*, which runs by wire No. 1 through magnet *C* on double circuit instrument *A*, front spring wire No. 3, to battery *x*, causing the front spring to open and back spring to close, the closing of which completes a circuit from battery *F*, through wires Nos. 4 and 5, back contact spring wires 6 and 7, through the bell, which continues to ring until the train reaches track instrument *b*, when it closes a circuit through wire 8, restoring magnet *d*, wire

PLATE VI.

Fig. 1.



Switch Machine

Fig. 2.

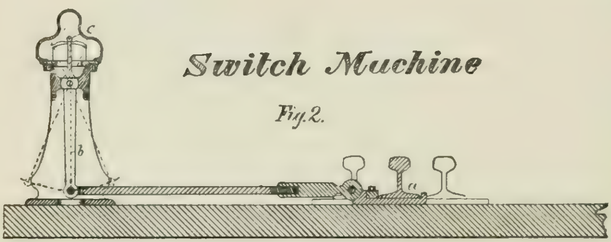
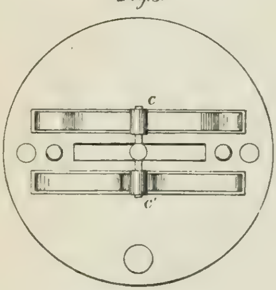


Fig. 3.



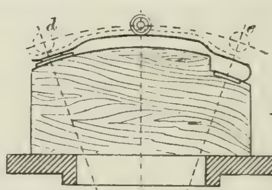


Fig. 4.

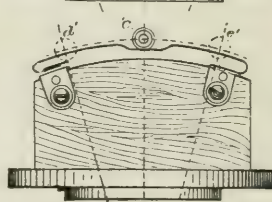


Fig. 5.

No. 9; relay magnet, wire 10, to battery *x*, thereby restoring the double circuit instrument and stopping the operation of the bell. The introduction of the relay, in this case, causes the bell to ring if any of the wires are crossed or grounded; for instance, if wire No. 1 is grounded, the relay magnet will be actuated, closing the circuit from battery *x*, through wires 4 and 10, spring *e*, wires 11, 6 and 7, to the bell. The operation is precisely the same on the other track.

In *Fig. 2*, trains approaching in the direction of the arrow No. 2 break the circuit at track instrument *a*, which passes through wire No. 1, track instrument *b*, wire 2, front spring on double circuit instrument, magnet *C*, wire 4, to the battery, closing the bell circuit by means of back contact spring. Trains reaching track instrument *C* restore the instrument by closing the circuit through wire No. 5, restoring magnet *d*, wire 6, relay magnet and wire 7 to battery, thereby stopping the bell. The train, on reaching track instrument *b*, unlocks the instrument, but it is restored by track instrument *e*. The operation is the same in the opposite direction.

The RAILWAY CAB ELECTRIC SIGNAL COMPANY.

DISTINCTIVE FEATURES.

(1.) The signal of danger is given audibly on the locomotive.

(2.) The signal continues to sound until interrupted by manual action.

(3.) The electric generator is movable, being a dynamo machine, carried on the locomotive, and actuating any portion of the road line, without local or fixed sources of electric current.

(4.) The advantage of a dynamo current in being free from the irregularities of batteries.

(5.) The use of a normally closed circuit, by means of the wheels of the locomotive, and the rail, to restrain the audible signal on the locomotive, and the interruption of such current on the rail to sound the signal.

(6.) The absence of force, or an open circuit producing the signal.

(7.) The small number of mechanical parts used, and the consequent minimum of original cost and repair.

The operation of the system will appear from the following diagrams and explanations:

The principle of this signal is as follows:

A locomotive is provided with an electric generator, or dynamo machine run by a small motor fed with steam from the boiler.

The two poles of the dynamo terminate by means of wires, one to the body of the locomotive, and one to the tender frame of the same, both having metallic contact with the rails by means of their wheels. These two points, or terminals formed by the wheels, must be insulated from one another; so that when on the rail, the wheels of the locomotive and the wheels of the tender are only connected together electrically by means of the rail. Where wood frames are used in tenders this insulation is already done; with iron frames the draw bar must be insulated.

We thus have a closed circuit in action by means of the dynamo, locomotive, tender, and the rail.

This closed circuit passes through a magnet in the cab which holds an armature to itself. When this circuit is interrupted, or opened, the armature leaves its magnet, and in so doing, by lever action, operates a bell, or whistle valve.

These signals continue to sound until the armature is returned by hand to its magnet, and held in place by the current. The interruption or opening of the circuit to cause the armature to leave its magnet, is made by insulating two abutting rails, one from another, so that when the locomotive wheel is on one rail, and the tender wheel on the abutting rail, the insulation between the rails will cause the circuit between the wheels to be interrupted or opened, when the consequent signal is given, by the armature leaving its magnet. The two parallel rails are insulated similarly, to cut the circuit for the wheels on both sides.

Thus an interrupted or opened circuit formed as described, gives an audible signal on the locomotive; this is the primary idea.

These signals are worked and controlled as follows:

From two insulated abutting rails, separate wires are led, to join which would destroy their insulated condition.

These wires are led any given distance for any signal purpose,

terminating at a switch—a draw-bridge—a station—at block points—or any other point from which a locomotive may be signaled, or which a locomotive may signal. By suitable parts controlled by magnets, so as to contact, and not to contact, these wires are opened and closed—as the case may be—at the points where they terminate.

If a switch is closed, the wires are closed; if a switch is open, the wires are open. Then when the insulated rail joints at the wires interrupt—as before shown—the current through the rail from the locomotive to the tender, such current must follow the wires leading from the two rails. Thus fundamentally, if the two wires are closed at any remote signaling point, the locomotive circuit will remain closed when passing the insulated joint where these wires join the rail. If the two wires are open at any remote signaling point, the locomotive circuit in the same position will be opened, the armature must leave its magnet, and the signal be sounded on the locomotive, while passing over the insulated joints.

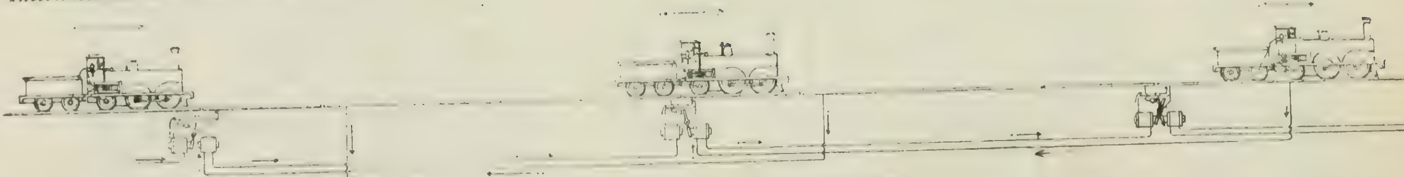
Thus a switch, bridge, station, block, or any point, "danger" means open circuit, and signal to locomotive, while "safety" means closed circuit, and no signal.

Thus a locomotive in motion forms a moving closed circuit on the rail, which is continued closed, or it is opened, as there may be safety or danger in its path.

EXPLANATION OF DIAGRAMS.—*(See Plate XI.)*

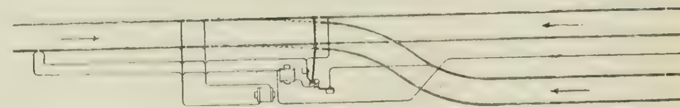
In the double track block sketch, three locomotives are shown in three different modes of action—the locomotives being a mile or more apart. All the locomotives show the circuit from the dynamo machine on them, terminating in the wheels of the locomotive and the tender. The rail plan shows insulated rail points to actuate the relay magnets, and similar points to receive danger alarm signals—the first being always in advance of the second. The circuits are the same for each block space, and are marked similar to the locomotives.

—— Locomotive - ——— } has formed a circuit of similar mark, over an insulated rail joint at a relay actuating point, actuating the near relay magnet in its circuit, to separate the contact points of the relay, and thus indicate at its danger alarm

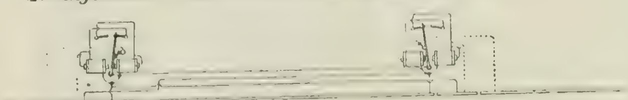


Plan of Double Track Block Signal Sections

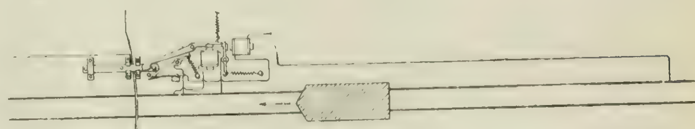
Arrangement of Single Track Block Signal Sections



Plan of Switch Signal, 3 Points



Plan of a Block Signal Section for Single Track



Plan of Draw Bridge Signal, and Lock

Plan of Signal to Engine from Depot, and Signalling Depot

Railway Cab Electric Signal Co.'s System.

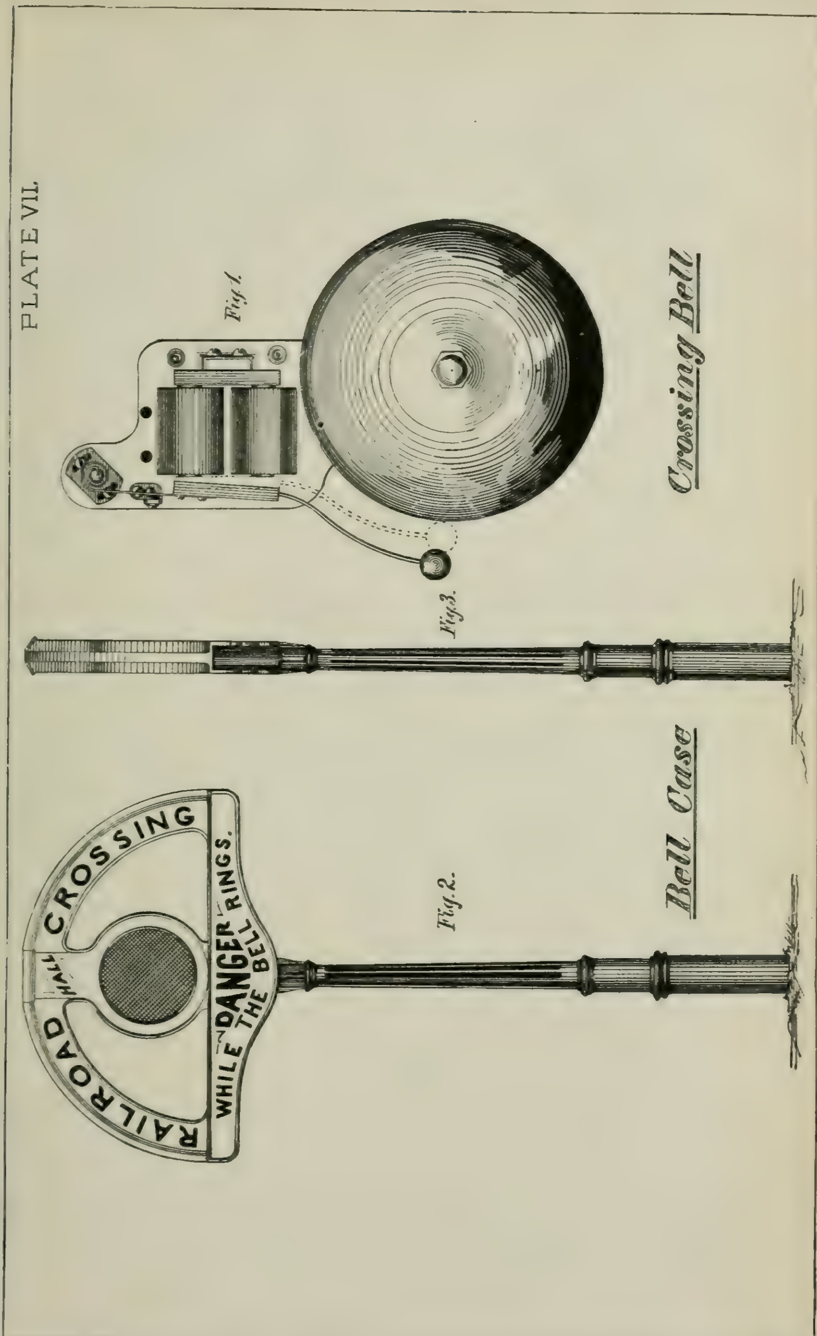


PLATE VII.
Fig. 1.
Crossing Bell
Fig. 3.
Fig. 2.
RAILROAD CROSSING
HALL
DANGER
WHILE THE BELL RINGS.
Bell Case

rail point, and has also actuated (on the same circuit) the magnet of the remote relay, to close the contact points, and thus set it at "safety," at its danger alarm rail point.

—— Locomotive - - ——— } is over the insulated joint of a danger alarm point, set at "safety" (or the points in contact) by locomotive - ——— }, as just described, and there being a path for the circuit from the wheels of locomotive - - ——— } by the rails and wires through the points in contact, no signal is received on such locomotives, the mile ahead being at "safety" for its advance.

—— Locomotive - - - ——— } is approaching an insulated joint of a danger alarm rail point, where the contact points of the relay have not yet been set together, or at "safety" by the circuit and locomotive - - ——— }, so locomotive - - - ——— } will be signaled when over that point, as the circuit from the rail through the contact points will be broken, there being then no path for it from wheel to wheel.

The wire connections all set the near relay magnet at "danger," and the remote relay magnet at "safety." That is opening the contact points at the near relay and closing them at the remote relay.

The plan of a single track block section shows how the circuits are made, so that a locomotive entering at either end, sets both before and behind at "danger," and in leaving the block sets both these points to "safety." In the sketch, the points are shown in contact, or at "safety," and dotted lines show the circuits to the alarm danger points on the rail. There being, as in double track sketch, relay actuating rail points, and alarm danger rail points.

The arrangement of single track block stations, shown by the sketch above, the last one exhibits how the section circuits are arranged to lap each other in series of threes; so that in no case can two locomotives be within a given distance, without receiving an alarm signal at an alarm danger rail point, which has been set at danger at a relay actuating rail point.

The switch signal sketch shows the points in contact (or circuit closed for safety) for the main line, and open for danger for the siding. If the switch was turned for the siding, it would close that circuit, and open one for the two points on the main line. The circuit through the magnet is to lock, or ring a bell at the switch. This can only be done when the switch is at "safety" to the line of

rail in use. When it is not so placed, there can be no circuit through the magnet, and the locomotive is signaled at the rail point where the wires terminate. The other circuit and magnet unlock the switch, or stop the bell, in passing.

The Draw-Bridge Signal shows a bridge bolted, and the bolt locked. By lifting the locking lever and pulling the bolt, the two contact points held together by the bolt separate, and the locomotive at the remote insulated danger alarm rail point would find no circuit, and would receive a signal. When the bridge is bolted, the two contact points are brought together, and the circuit can then pass from the remote danger alarm rail point to the magnet to lock the bolt. The other circuit and magnet are to unlock the bolt in passing.

The Depot Signal shows at the point farthest from depot, a circuit from the rail to shunt on a local current to ring a bell at the depot. The nearer rail point circuit runs to an electric switch in the depot, whereby the circuit can be opened or closed. By such switch, the locomotive can be signaled or not, by this means, at the rail point where the circuit or wires terminate. The circuit shown from the rail point when past the depot, stops the bell at the depot which the approaching locomotive had actuated.

As a preliminary to critical examination of the operation of these signals upon the railroads where they are in actual operation, the writer obtained from three gentlemen, who had had large practical experience in the use of signals of various kinds, a statement of what each would consider cardinal requirements in an ideal system of signals. Of the gentlemen who kindly responded to my inquiry in this direction, Mr. Chamberlain, the Superintendent of the Providence and Worcester Road, was the first to make a systematic study of the signals employed upon any road and to place before the public a clear and succinct tabular view of the work done under the system in use and of the number of failures from the various causes which rendered the system inoperative within a given period of time.

Mr. McCrea, the General Manager of the Pittsburg, Cincinnati and St. Louis Railway Company, is well known as a zealous advocate of every precaution which can add to the safety and efficiency of railway service.

Mr. Blodgett, in his capacity as electrician of the Boston and

Albany Railroad, has had wide experience both in the theory and the application of electricity to the problem under consideration.

The following are the communications sent in answer to my inquiry :

PROVIDENCE AND WORCESTER RAILROAD COMPANY.
SUPERINTENDENT'S OFFICE.

PROVIDENCE, R. I., January 9, 1885.

PROF. WM. A. ROGERS, *Harvard College Observatory, Cambridge, Mass.*

Dear Sir:—In compliance with your request, and as per my promise, I would suggest the following questions relative to the systems of electric signals on the different railroad lines:

(1.) By what system are your signals operated? Is it by open or closed circuit?

(2.) Is the normal condition, *danger*, when any accident occurs to the mechanism of the signal or any part of the apparatus?

(3.) Does your system show *danger* immediately upon a train entering the block protected by signals?

(4.) Will signal remain at *danger* in case a train breaks apart in one or more places, and will it remain at *danger* in case the first section or engine has passed out of the block and entered the section or block ahead?

(5.) Will signal show *danger* in case of a broken rail, or an obstruction by rails being placed across the track?

(6.) In case switches are set wrong, or are being used within a block, will the signal which protects that block show *danger*? If so, can you fully rely on it to protect you from a rear collision?

(7.) Will your system show *danger* when a car is left on a side track, in such position as to obstruct the main track?

(8.) Will your system of automatic signals, under any conditions, show *safety* when *danger* should be shown?

If so, under what conditions?

(9.) Can your system of signaling be operated from any point desired, by hand, as effectually as by train while in section?

(10.) Is the apparatus employed entirely free from atmospheric influences?

(11.) Is your system arranged so that all the switches in block can be electrically locked and not unlocked during the time that the block is obstructed by a train or otherwise?

(12.) Does your system permit the over-lapping of one or more signals, so that one or more signals will remain at *danger* until the whole train has passed from the block and over part, or the whole, of the next block?

(13.) In case one railroad crosses another at grade, or at a junction, or a branch road diverges from the main track, can your signals be so arranged that they will block out (by home or distance signals) trains in either direction, which are opposed to the safety of any train using main track, or vice-versa?

(14.) Will such signals work automatically from all switches, and work by hand from switch-houses or otherwise?

I think the above interrogations cover the important points in the matter of signals.

In relation to the interlocking system of switches, I am not prepared to make any statement, as we have no equipment of the same on this road, and I have not had the opportunity to make such a thorough investigation as would warrant a positive opinion as to their merits.

I shall be pleased at any time to give you any information desired, if in my power, and hope the questions propounded herewith will meet your approbation. Yours, very respectfully,

W. E. CHAMBERLAIN,
Superintendent.

[COMMUNICATION FROM MANAGER McCREA.]

The requirements of an Automatic Electric Block Signal System, are briefly:

(1.) That the system should be reliable beyond question, so that in case of trouble, the responsibility can readily be placed.

(2.) The signals should indicate either "stop" or "go ahead;" never cautionary, unless as a distant, indicative of a Home Signal in advance.

(3.) The signal in its "clear" position should indicate an entirely unobstructed track, and should hold all conflicting signals to "danger," and lock all switches (if possible, in the position to act as throw-offs), which, by being moved during the passage of a train running according to a signal, might either throw it from the track, divert it from the intended course or allow another train moving in either direction, to collide with it.

(4.) Semaphores should be used to govern running tracks. On roads which run to the right, the arm should point to the right of the direction in which the train is moving, and on roads which run to the left, the reverse should be the case—this for the purpose that direction may be indicated. It is not, in all cases, possible to place the signals for the same direction, on the same side of the track, consequently a disc signal, even if shielded on the back, cannot (unless by rule, or of a distinguishing form, neither of which is hardly to be considered good practice) be made to indicate direction.

(5.) Pot Signals should be made to govern sidings, in order that as few signals as possible be displayed on the main running tracks, and again, that a short sight only be given, so as to compel an engineman, while on any subordinate track, to keep his train under complete control.

(6.) The current should hold the signal to "safety," so that in case of failure of the battery, the signal would automatically indicate danger.

(7.) On a single track the Block Section should so over-lap, that no two trains moving at speed in opposite directions, should be allowed in adjoining sections, to approach each other at the same time.

(8.) Provision should be made to indicate the position of all signals in adjacent Block Sections, to the train order or telegraph office.

(9.) Atmospheric disturbances should be provided for, so that in no case could an electric charge hold a signal at "safety."

Yours very truly,

JAMES MCCREA,
General Manager.

[COMMUNICATION FROM MR. BLODGETT.]

PROF. WM. A. ROGERS, *Chairman Committee on Railroad Signals*, FRANKLIN INSTITUTE *Exhibition, etc., Philadelphia.*

My Dear Sir:—In response to your kind invitation some time ago to give you at convenience my views of what an ideal railroad block signal should be and do, I submit them herewith, simply stating, by way of preface, that I have made no attempt to discuss the question broadly, or the merits of any particular system; but merely to outline the subject, and offer some general suggestions. I am committed to no system of signals farther than warranted by its conformity to the principles here laid down, and I try to deal with all in fairness, from the standpoint of one who would recognize the merits and point out the defects of each, rather as a stimulus to further development than as a cause for discouragement.

Interlocking apparatus, whereby the positions of switches and signals relating to a particular piece of track, are so dependent on each other that the signal for a train to proceed in a proposed direction cannot be given until that route has been made complete, while during the existence of such signal, no signal can be given for a train to pass over any conflicting route, has been, in my opinion, brought much nearer practical perfection than line block signals, so-called.

Interlocking is in use in this country to a limited extent at junctions, grade crossings of railroads, and in yards where the movements of trains over the same tracks in the same or opposite directions are very frequent.

By far the greater number of such devices which have been invented simply warn the engineer visibly or audibly of danger potential or actual, but would not prevent a disaster should he disregard the warning, or lose control of his train. A few systems provide that contact with some part of the apparatus shall forcibly remind the engineer of his neglect, and in one or two inventions it is impossible for him even to reach the danger point.

In the best systems of interlocking where the mechanical interdependence of switches and signals has been made as perfect as human wisdom has yet discovered how to do it, and supplemented by electric appliances dependent on the movements of the trains, an accident would seem well-nigh impossible.

The application of block signals to a line of railroad is commonly made by dividing it into longer or shorter sections, according to circumstances, each of which is provided with one or more signals designed to show to a train

whether or not it may proceed over the portion of the track to which the signal belongs. Of all the accidents which may happen to railroad trains, I think there are but two against which we can reasonably expect block signals will provide, viz.: the presence of another train in dangerous proximity, and a broken or displaced track.

Recognizing that these two are by far the most fruitful sources of accident, many inventions have been made which professed to furnish complete protection against them, but thus far with only partial success. At first mechanical devices were used, operated by some person designated for the purpose. This is, to a large extent, still the case. They are, however, always open to the following grave defects: (1) the signal man's perception of danger may be wrong, (2) his judgment may be defective, (3) the mechanical appliances he controls may work imperfectly and lure a train into the danger they were designed to guard against. Appalling disasters have been caused by each of these, which we afterwards saw might have been easily prevented.

Experience has demonstrated that whenever mechanical principles can be substituted for human perception or judgment, a very great increase in certainty and safety is the result.

This fact has been gradually more and more recognized by those who have to do with railroad signaling, and many attempts have been made to invent a system which should be as far as possible independent of perception or judgment in their operation, and be governed partially or wholly by the movements of the trains or the condition of the track (whether occupied or unoccupied) or both.

The problem simply stated is this: Given the complicated and varying train movements over a railroad, to devise means whereby each of these movements which can imperil any other train, shall be signaled to such train in ample time to allow effective measures for its safety to be taken; also that any displacement or interruption of the track over which a train is to pass shall be at once made manifest, and that each of these shall be done with certainty and regularity by the apparatus itself; that is, it shall be *automatic*.

I must here, however, frankly say that no device I have ever seen perfectly fulfils these requirements, and some do not even profess to do so. Others make the pretence, but when put to the test, prove unreliable. It would seem at first sight as though there might be an indefinite number of such devices, differing from each other only in details of construction or operation, moved by clock-work and a weight or spring, by compressed air or wind-power, by a running stream or hydrostatic pressure, by the electric current or the attraction of a magnet, or by a combination of two or more of these principles, but practically we are confined to quite a narrow range. For instance, the condition that a signal shall show the occupancy of a section by a train can only be completely met by an instrument which shall continue to show danger as long as any portion of a train, even a single pair of wheels remains in the section, or in dangerous proximity thereto, and shall at once indicate this, no matter how the obstruction came there.

Again, the requirement that a signal shall show whether or not the track is continuous through the whole of the portion the signal governs, seems to me

to positively exclude all such systems as operate by track or hand instruments, and can be set to "danger" or the reverse only at a few detached points in the section. I know of but one method by which this requirement can be met, viz: by an electric current through the rails, the breakage or displacement of any one of which shall prevent its passage. This can be done potentially by an open circuit, which is completed for the current to pass at the moment when we wish, or actually by a closed circuit through which there is a continual flow of electricity. The latter is, therefore, preferable, though at a somewhat greater cost of maintenance. In either case, the display of a danger signal, or the reverse, should depend on the occupancy and continuity of the track, and not on the previous operation of some other part of the system.

An ideal railroad signal would combine the good points of all those which have yet appeared. These seem to be the requirements of such a system, as developed by past experience.

At junctions, crossings, draw-bridges and other dangerous or complicated places, interlocking apparatus will be used, so connected that the passage of trains over conflicting routes at the same time is *mechanically impossible*; this will be further made sure by the use of electric currents controlling and limiting the signal man's operations to such as are perfectly safe and proper, and to indicate to him the movements of trains.

"The offer of a right of way and its acceptance by a train, should prevent interference in any way with its passage in safety, unless the right of way is voluntarily relinquished, when it may be given to another train. *It should, however, always be in the power of the signal-man to put a signal instantly to danger and stop a train* to which he may have given a right of way, whenever any contingency arises which makes that desirable. No mechanical or electric device should ever be so attached to interlocking apparatus as to lock a signal in an "all clear" position, but the locking should take effect on the first movements of all conflicting routes."

In line block signals, I think the following principles should be observed:

The signal should be, as far as possible, *automatic*. It must be prompt, positive and efficient in action. The information conveyed by it must be instantly and perfectly intelligible; there must be no delay or ambiguity in interpreting its meaning. It should, therefore, show three things, and only these: (1) That the track over which the train is to proceed is continuous and unoccupied through the whole length to which the signal applies; (2) that it is *not* continuous or is occupied; (3) that the signal is itself out of order and must not be depended on.

Much of the value of a signal will be due to the kind, form, position, color and size of the instrument, and these will commonly vary somewhat with circumstances, but should be as uniform as possible. A visible signal can usually be seen farther than an audible one can be heard. The form, position and size should be such that the signal will be plainly visible from the first moment when its indication could be of service; also such that it cannot be confounded with something else in the same vicinity. The semaphore arm has probably given better results than any other form of signal.

The color of a signal should be in marked contrast to the back-ground against which it is to be seen, and if more than one color is used there should be as much difference between them as possible.

When practicable, the indication of the signal should be readily perceived by *both* the color and position, which ought to be different for each different indication, but signals for the same purpose should invariably mean the same thing along the entire line of road.

However complicated its functions may be, a signal should be mechanically a simple machine, of few parts, not liable to derangement, easily put in order when necessary, and of great durability. It should also be entirely independent of weather or other atmospheric influences. Finally, it should be cheap enough in first cost and in maintenance to make its use depend entirely on its merit, and not at all on the question of expense.

The use of any such device ought to be as an addition to, and never as a substitute for, the utmost care and watchfulness human forethought can take. I am, sir, with great respect, very truly yours,

Geo. W. Blodgett,
Assistant Engineer, Boston and Albany R. R.

Boston, July 11, 1885.

It would be too much to expect that either of the systems under consideration should perfectly meet the demands of an ideal system so clearly defined in the preceding communications. Many improvements, resulting from experience, have been made since electric railway signals were first introduced, and minor improvements will doubtless continue to be made, but it will be seen from the data given below that the systems in operation are now so nearly perfect that their use in the daily operations of a road is no longer an experiment. The old Hall system, the first to be introduced in this country involved the use of an open circuit. It was only by the expenditure of many thousands of dollars and as the result of a multitude of experiments that it was demonstrated that the conditions of the problem require a closed circuit. It is to be noted in this connection that the exhibit of the Wharton Switch and Signal Company relates to the new Hall system, in which the closed is substituted for the open circuit.

This gradual improvement both in the application of fundamental principles and in the perfection of mechanical details, is well illustrated in the changes which have been made in the form of the relay, used by the Union Switch and Signal Company.

The following illustrations and description relate to the instrument known as the Westinghouse patent

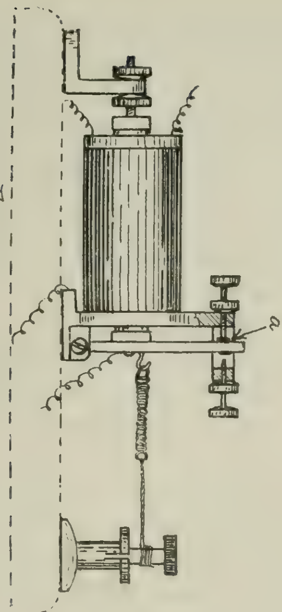


Fig. 19

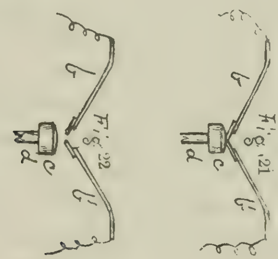


Fig. 22

Fig. 21

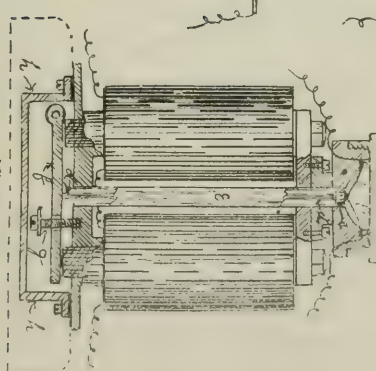


Fig. 20

Fig. 19 shows the style of relay, formerly used in connection with these signals, and *Fig. 20* shows the improved style now used.

By reference to *Fig. 19*, it will be seen that this is the style of relay used in telegraphy, and its contact or local circuit closing point *a* is very small and exposed to the atmosphere, and is liable to become covered with dust in such a way as to keep the local circuit broken when the armature is attracted.

The means of adjustment on this relay are too easy of access, and they are liable to be interfered with in such a way as to cause the apparatus to work improperly.

Referring to *Fig. 20*, it will be seen that the contact springs *b*, *b′*, which are closed or pressed together by the head *c* of the rod *d*, are fastened to a hard rubber block and covered by a brass cap, which is screwed down over them, thereby enclosing them in a dust-proof case.

The rod *d* passes down to the tube *e*, and rests upon the armature *f*, moving down with the armature when it is released, thereby allowing the springs *b*, *b′* to separate and break the local circuit, and raising again with the armature when it is attracted by the magnet, and presses the springs together again, closing the local circuit. The screw *g* controls the drop of the armature and is the only adjustment used in this form of relay.

The cap *h* is fastened on to the base of the instrument by small screws and encloses the armature *f*, screw *g*, and lower end of the rod *d*, in a dust-proof chamber.

Fig. 21 is an enlarged sketch of the contacts and shows the local circuit closed.

Fig. 22 is the same, showing local circuit broken. It will be seen that when the springs *b*, *b′* are pressed together by the head *c*, there is a good contact at the end of the springs, and also through the head *c*.

•

In estimating the commercial and the practical value of any system of signals, three facts must be taken into consideration:

(1.) It is to be considered chiefly as an AID in preventing accidents, by compelling caution on the part of the employés of a road.

(2.) Even if the signals fail to operate, even if a safety signal is shown when a danger signal should be displayed, this failure does not introduce any additional element of danger, over that which would exist if there were no such system of signals in use.

(3.) The whole question of the use of automatic signals in any case resolves itself into a question of railroad economy. The cost of maintenance would not probably be a very serious matter in any event, but no road could endure the delay and interruption caused by the frequent display of false danger signals. It is obvious, therefore, that the mechanism of any system on trial must be so perfect that the number of failures shall not be sufficient to cause appreciable delay in the running of trains.

A limited personal examination of the operation of any system could not in any event count for much as a test of its merits. Still it was thought desirable to make this inspection. The writer, through the courtesy of Superintendent John Adams, of the Fitchburg Road, passed over that part of the line on which the signals are located, several times on different engines. In no case was there a failure in the operation of the signals.

President Watrous, of the New York and New Haven Road, kindly furnished a pass for a trip on any engine over that road for the purpose of witnessing the operation of the Hall Signal. A very interesting and satisfactory trip was made on the fast night express.

By the courtesy of Thos. C. Miles, General Manager of the Railway Cab Electric Signal Company, an engine was placed at the disposal of the writer for an examination of the system represented by this company at the station on the Staten Island Railroad, at which all the preliminary experiments on this system were made. This examination was entirely satisfactory. All the tests made, indicated a high degree of certainty in the operation of the signals.

Investigation of the Performance of the Signals upon the Roads upon which they are in use.

THE SIGNALS OF THE UNION SWITCH AND SIGNAL COMPANY.

The signals of this company are in use upon all the roads running out of Boston, except one. The Fitchburg Road was the first to adopt the system, in 1880. At present, the number of trains operated daily by twenty-seven signals is 152, of which 114 are regular and 38 are irregular. Every engineer is instructed to fill out a blank, of the following form, whenever a signal indicates danger from any cause. This report of the engineer, however, indicates only the probable cause, as apparent at first sight, of the danger signal. This report is returned to the office upon his arrival at Boston. With this report as a general guide, a signalman is sent to investigate the real cause, and his return is made upon the stub blanks. For the first two or three years, the maintenance of the signals was in the hands of the signal company, but during the past two years the railroad company has had their care in charge.

[*Form of Blank.*]

FITCHBURG RAILROAD.

ELECTRIC SIGNAL REPORT.

188

MR. JOHN ADAMS, *Gen'l Superintendent.*

Dear Sir:

Outward train No.

Inward train No.___

Extra train No.______

at about _____ o'clock, ___ M. found Signal No. _______ at DANGER.

I report the cause (if ascertained) by writing *yes* opposite the proper question below:

Was Train in Section__________

Was Hand Car or Truck in Section____

Was Rail Broken in Section_______

Was Track being Repaired______________

Was Switch open in Section____

Was Switch unlocked in Section_

Was Cause unknown________

(If the danger signal was found at SAFETY and did not turn to DANGER as it should, write "yes" here)__________

Engineman.

THE UNION SWITCH AND SIGNAL COMPANY.

Gentlemen:—Will you please investigate the above report, and advise me what caused the signal to remain as stated.

Yours truly,

JOHN ADAMS, *Gen'l Supt.*

188

MR. JOHN ADAMS, *Gen'l Supt.*

Dear Sir:—In regard to the above, I have to say,

Yours truly,

For the Union Switch and Signal Company.

The returns from these blanks have not been posted in tabular form at the office, but Superintendent Adams kindly placed the blank returns from March 1 to August 1, 1884, in the hands of the writer, from which the following results were obtained :

Indicated Cause.	*Number of Indications.*
Train in section,	67
Switch open,	36
Work in section,	25
Unknown,	16
Broken track wire,	42
Decay of switch frame,	1
Rails driven together at end of section,	1
Dust on platinum points,	2
Broken spring in signal switch,	2
Bad zinc in battery,	9
Rails connected by crossing wire,	5
Derangement of signal apparatus,	9
Guard wire broken,	9
Bad insulation,	12
Lack of blue vitriol in battery,	4
Broken switch,	1
Battery wire broken,	3
Broken frog wire,	4
Loose-headed rivet,	3
Relay burned out by lightning,	3
Relay out of adjustment,	2
Signal slow in turning,	1
Signal weight ran down,	2

The failures recorded below the dividing line are to be charged to the system, and they may be taken as a fair indication of the character of the failures likely to occur. The number of failures however, varies greatly upon different roads. For example, the number of cases of broken track wire is here forty-two, while upon the Providence and Boston Road there was not a single case for three of the corresponding months. This disparity well illustrates the great improvements in construction, suggested by experience, since the first introduction of the signals. It is to be noted also that nearly all of these failures would be prevented by the exercise of greater care in the supervision of the signals. A new plant, of the latest form of construction, would probably reduce the number of failures by at least one-half. Even here the ratio of the number of failures to the number of operations is

$$117 : 144 \times 252 \times 27,$$
$$\text{or} \quad 1 : 8374.$$

The records of the service on this road do not show the number of cases in which a safety signal was shown when a danger signal should have been exhibited. According to the testimony of the officers of the road, only three such instances have occurred. It should be said that this is much less than the average number on other roads, where a strict record has been kept.

THE SIGNALS ON THE BOSTON AND PROVIDENCE RAILROAD.

The first five miles of this road out of Boston are equipped with sixteen signals. The number of regular trains daily is 106; the average number of irregular trains being about 25 daily. Engineers are furnished with blanks similar to those in use upon the Fitchburg Road, but no permanent record is kept, on account of the satisfactory operation of the signals. By the kindness of Superintendent Folsom, a copy of the failures for two months in 1884 was made, viz., from June 23d, the date of the introduction of the signals, to July 23d, and for October, 1884:

Indicated Cause.	*Number of Indications.*
Loose connecting screw,	1
Spring failed,	4
Relay out of order,	12
Switch-box out of order,	4
Battery out of order,	3
Signal apparatus out of order,	4
Water on the track,	3

It is the testimony of the officers of the road that a safety signal has never been shown when a danger signal should have been set.

EASTERN RAILROAD.

Record of the Union Switch and Signal Company signals from January 1, 1881, to December 1, 1884:

Trains in section,	352
Imperfect connections at draw-bridge,	13
Signal apparatus out of order,	4
Lightning burned out relay,	7
Broken battery,	9
Broken switch stand,	4
Broken rail at end of section,	12

Broken wires,	110
Loose pin in switch,	6
Trouble with magnet,	10
Trouble with switch instrument,	10
Signal weight run down,	6
Falling weight caught,	2
Banner caught,	1
Unknown,	6

Here, as on the Fitchburg Road, the greatest trouble appears to be with broken wires.

BOSTON AND ALBANY RAILROAD.

The records of the operation of the signals upon this road are kept with the greatest care, and in the most systematic manner, under the direction of Mr. Blodgett, the Electrician in Charge. The following very complete summary was kindly furnished in answer to an application to Mr. G. R. Hardy, the Engineer of the road:

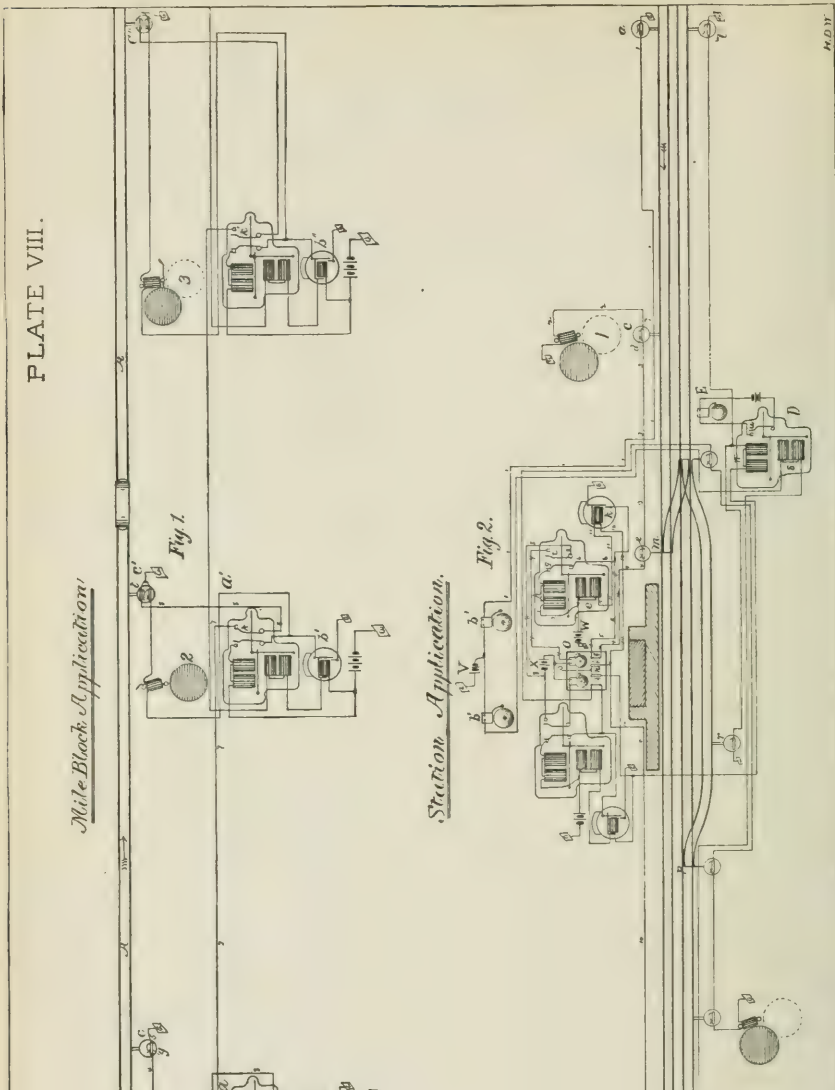


PLATE VIII.
Mile Block Application.
Fig. 1.
Station Application.
Fig. 2.

BOSTON AND ALBANY RAILROAD COMPANY.

DIVISION I.

Union Electric Signals. October, 1883, to October, 1884.

Number of Blocks in Operation, 51 to 81.

			Ratio to Number of Operations.	
No. of operations,		1,083,291.		
Stops for trains in section,	1,648.		$\frac{1}{657}$	
Stops for switching,	31.		$\frac{1}{34945}$	
Stops for broken rail,		1,698.		$\frac{1}{863}$
Stops for repairing track,	18.		$\frac{1}{60183}$	
Stops for using single track,	1.		$\frac{1}{1083291}$	
Stops for neglect of trackmen,	238.		$\frac{1}{4552}$	
Stops for neglect of trainmen,	31.		$\frac{1}{34945}$	
Stops for neglect of towerman,	1.		$\frac{1}{1083291}$	
Stops for neglect of station agent,	83.		$\frac{1}{13052}$	
Stops for neglect of switchmen,	3.	696.	$\frac{1}{361097}$	$\frac{1}{1556}$
Stops for neglect of signalmen,	293.		$\frac{1}{3697}$	
Stops for neglect of carpenters,	4.		$\frac{1}{270893}$	
Stops for neglect of U. S. & S. Co.'s men,	42.		$\frac{1}{25793}$	
Stops for testing circuit,	1.		$\frac{1}{1083291}$	
Stops for signal failed to change, showing safety,	179.	502.	$\frac{1}{6052}$	$\frac{1}{2158}$
Stops for signal failed to change, showing danger,	323.		$\frac{1}{3354}$	
Stops for climatic conditions,	957.		$\frac{1}{1132}$	
Stops for unlighted signals,	199.	1,591.	$\frac{1}{5444}$	$\frac{1}{681}$
Stops for cause not known,	435.		$\frac{1}{2490}$	
Stops unnecessary,		2,789.		$\frac{1}{388}$
TOTAL,	4,487.		$\frac{1}{241}$	

(Signed) G. W. BLODGETT.

Approved, G. R. HARDY.

BOSTON AND ALBANY RAILROAD COMPANY.

DIVISION 2.

Union Electric Signals. October, 1883, to October, 1884.

Number of Blocks in Operation, 24.

			Ratio to Number of Operations.	
No. of operations,		251,976.		
Stops for trains in section,	4,290.	4,340.	1/59	1/58
Stops for switching,	9.		1/27997	
Stops for broken rail,	31.		1/8128	
Stops for repairing track,	10.		1/25198	
Stops for neglect of trackmen,	13.	60.	1/19383	1/4200
Stops for neglect of trainmen,	1.		1/251976	
Stops for neglect of station agent,	5.		1/50395	
Stops for neglect of signalmen,	41.		1/6146	
Stops for signal failed to change, showing safety,	46.	204.	1/5478	1/1235
Stops for signal failed to change, showing danger,	158.		1/1595	
Stops for climatic conditions,	213.	702.	1/1183	1/359
Stops for unlighted signals,	404.		1/624	
Stops for cause not known,	85.		1/2964	
Stops unnecessary,		966.		1/261
TOTAL,	5,306.		1/47	

(Signed) G. W. BLODGETT.

Approved, G. R. HARDY.

BOSTON AND ALBANY RAILROAD COMPANY.

DIVISION 3.

Union Electric Signals. January, 1884, to October, 1884.

Number of Blocks in Operation, 4 to 8.

			Ratio to Number of Operations.	
No. of operations,		114,693.		
Stops for trains in section,	6,249.		1/18	
Stops for switching,	4,856.	11,125.	1/24	1/10
Stops for broken rail,	4.		1/28673	
Stops for repairing track,	16.		1/7168	
Stops for neglect of trackmen,	25.		1/4588	
Stops for neglect of trainmen,	1.	67.	1/114693	1/1712
Stops for neglect of station agent,	3.		1/38231	
Stops for neglect of signalmen,	38.		1/3018	
Stops for signal failed to change, showing safety,	85.	336.	1/1349	1/341
Stops for signal failed to change, showing danger,	251.		1/457	
Stops for climatic conditions,	176.		1/652	
Stops for unlighted signals,	79.	425.	1/1452	1/270
Stops for cause not known,	170.		1/675	
Stops unnecessary,		828.		1/139
TOTAL,	11,953.		1/10	

(Signed) G. W. BLODGETT.

Approved, G. R. HARDY.

BOSTON AND ALBANY RAILROAD COMPANY

DIVISION 4.

Union Electric Signals. January, 1884, to October, 1884.

Number of Blocks in Operation, 6.

			Ratio to Number of Operations.	
No. of operations,		39,398.		
Stops for trains in section,	1,405.		1/28	
Stops for switching,	83.	1492.	1/475	1/26
Stops for broken rail,				
Stops for repairing track,	4.		1/9849	
Stops for neglect of trackmen,	9.		1/4378	
Stops for neglect of trainmen,		12.		1/3283
Stops for neglect of station agent,	1.		1/39398	
Stops for neglect of signalmen,	2.		1/19699	
Stops for signal failed to change, showing safety,	107.	201.	1/368	1/196
Stops for signal failed to change, showing danger,	94.		1/419	
Stops for climatic conditions,	60		1/657	
Stops for unlighted signals,	136.	278.	1/290	1/142
Stops for cause not known,	82.		1/480	
Stops unnecessary,		491.		1/80
TOTAL,	1,983.		1/20	

(Signed) G. W. BLODGETT.

Approved, G. R. HARDY.

The signals upon this road were first used in April, 1882. The total number is about 100. The distance between the signal stations is about one-fourth of a mile as far as the Providence crossing, about one-half mile apart for two miles out, and for the remaining nine miles about one mile apart.

The numbers in the first column represent the useful work of the signals. The numbers in the second column represent the failures due to neglect on the part of employés in charge of the signals, and in the third section, the failures to be charged to the system itself. The figures in bold-face types represent the totals in each column.

It will be noticed that the number of failures due to climatic conditions is unexpectedly large. They are for the most part due to the completion of the circuit between the rails through water containing a large percentage of salt standing upon the track.

It will be seen also that the number of cases when a safety signal was shown when a danger signal should have been set, is apparently much larger than upon other roads. This is without doubt largely due to the strict accuracy with which the record has been kept. The number of broken wires is not shown separately in this report, but it is comparatively very small. The connections between the rails are now made with two wires instead of one, as formerly.

PROVIDENCE AND WORCESTER RAILROAD.

The study of the operation of the signals upon this road has been reduced to a science by the Superintendent, Mr. W. E. Chamberlain. His reports to the Railroad Commissioners of Rhode Island may be said to form the first complete demonstration from a discussion of the records kept of the feasibility of this system of signals in the ordinary operations of a road.

These signals were first put in operation in April, 1882. There are twenty eight on the first division, which extends from Providence to the Boston Switch at Central Falls. The signals upon the second division, which extends from Boston Switch to Worcester, thirty-nine miles, were introduced November, 1883. They number forty-eight. In the operation of these signals, engineers are governed by the following instructions:

(1.) When a signal shows danger you will come to a full stop before entering the block which said signal protects, or, if a special signal, you will come to a full stop before covering the switches it protects. You may then proceed carefully, but under full control, expecting to find the block obstructed, or a switch set wrong, or a rail broken. If no trouble is found and the next signal is at "safety," you may proceed at usual speed, but if at danger proceed as before from block to block until the obstruction is passed. Report all stops or detentions on blanks furnished for that purpose.

(2.) All signals now in use, and all rules in force governing the safety of trains, will continue to be used until further orders.

(3.) Study carefully the description of blocks and special signals.

Road masters and section foremen will thoroughly post themselves in regard to the working of the electric signals, and teach their men to keep the track wires and insulations in perfect order, bearing in mind that on you, in a measure, depends the proper working of the signals. No rail or frog must be changed (except in case of emergency), unless the foreman in charge of signals is on hand to make the proper connections.

At my request, Mr. Chamberlain has kindly made up a summary of the operation of the signals to October, 1884.

It is as follows:

ELECTRIC SIGNAL REPORT.

(FIRST DIVISION P. & W. R. R., DISTANCE 5 MILES.)

From October 1, 1883, to October 1, 1884.

The small figures in the spaces, indicate the number of failures; the large ones, the number of trains stopped.

Letters indicate switch signals only. Figures indicate track and switch signals.

A	B	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	C	20	F	X	H_1	H	D_1	D	TOTAL.			TRAINS
		2	97	5	98	10	51	9	3	27		29	3	60	12	50	14	3	23	8	6				1		1	512	P. & W. trains stopped by B. & P. trains in section.		
																			1									1	B. & P. trains stopped by P. & W. trains in section.		
		1	55	1	80	10	39	3	4	21	20	13	7	14	10	8	12	3	5	3	3	1			1		1	315	P. & W. trains stopped by P. & W. trains in section.		
																1												1	Trains stopped by gateman at Pawtucket.		
			6	1	18		6	2	1	3	2	14	3	5	6	2	3	1	9		2							84	Trains stopped by unknown trains in section.		
							1		1				1															3	Trains stopped by hand cars in section.		
3		2	12						1		1			1	2		3								6		6	37	Trains stopped by switch being open.		
		1	12																									13	Trains stopped by switching in Providence Yard.		
																			1									1	A freight car left on main track by train breaking apart.		
										1																		1	Trains stopped by switching at cattle track.		
												5			3													8	Trains stopped by switching at Sayle's Turn-out.		
												12	1	12	40	1	21	2	7	5								**101**	Trains stopped by switching at Pawtucket.		
										$^{2}3$						$^{1}2$	$^{1}7$			$^{1}2$								**5**	Broken rails	stopped	14
								$^{1}1$		$^{1}1$					$^{1}1$													**3**	Switch boxes out of order	"	**3**
			$^{1}1$		$^{3}8$	$^{1}1$		$^{1}4$	$^{2}4$	$^{5}6$	$^{3}5$			$^{1}2$		$^{1}1$	$^{2}2$			$^{3}3$					$^{1}1$			**24**	Lights out	"	**38**
																													Failures on account of loose track wires	"	
				$^{1}2$	$^{3}7$	$^{2}3$	$^{1}3$			$^{4}9$	$^{6}9$	$^{1}1$	$^{5}16$	$^{1}1$		$^{2}2$	$^{1}1$		$^{2}7$									29	Failures on account of broken track wires	"	61
			$^{1}1$				$^{4}7$	$^{1}1$	$^{1}1$			$^{1}2$	$^{2}3$	$^{1}2$			$^{1}1$		$^{1}1$		$^{1}1$				$^{1}1$		$^{1}1$	16	Failures of machine	"	22
			$^{1}1$						$^{1}1$		$^{2}6$									$^{1}1$								5	Failures on account of weak current	"	9
	$^{1}1$											$^{1}1$	$^{1}1$			$^{2}2$		$^{1}1$	$^{3}3$		$^{2}3$							11*	Failures of battery	"	12
			$^{2}2$										$^{1}2$						$^{1}2$									**4**	Failures on account of track insulators giving out	"	**6**
									$^{1}1$																			1†	Failures on account of machines run down	"	1
			$^{3}4$	$^{1}1$			$^{1}1$	$^{2}3$		$^{2}2$				$^{1}2$	$^{1}1$		$^{2}2$			$^{1}1$					$^{1}1$			**15**	Failures on account of carelessness of employés,	"	**18**
		$^{2}5$			$^{1}1$	$^{2}2$	$^{1}2$		$^{1}1$		$^{2}7$			$^{1}2$		$^{1}1$			$^{1}1$						$^{1}1$			13	Failures on account of broken or crossed line or ground wires	"	23
									$^{1}1$		$^{1}4$								$^{1}1$									3	Failures for which no cause was found	"	6
			$^{1}1$																									1	Relay not adjusted high enough	"	1

79 Failures, not including lights out or carelessness, stopped 137 trains.

* 6 of these account carelessness. † Carelessness.

GRAND TOTAL FOR BOTH DIVISIONS.

Total number of signals on First Divison, ...	28
Total number of signals on Second Division, . . .	48
	76 signals.
Total number of operations on First Division for the 30 months to October 1, 1884, ...	1,366,386
Total number of operations on Second Division for the 10½ months to October 1, 1884, ...	371,304
	1,737,690 operations.
Total number of failures on First Division for the 30 months to October 1, 1884, ...	341
Total number of failures on Second Division for the 10½ months to October 1, 1884, ...	99
	440 failures.

Percentage of failures to operations on both divisions, ... ·000253

565 trains stopped on First Division by failures of signals during 30 months.

Total number of trains run on First Division during 30 months, . . 97,600

Percentage of trains stopped by failures, ... ·005789

165 trains stopped on Second Division by failures of signals during 10½ months.

Total number of trains run on Second Division during 10½ months, ... 15,471

Percentage of trains stopped by failures on Second Division, . . ·010665

Total percentage of trains stopped by failures on both divisions since signals have been in operation, ... ·006456

The writer has not had an opportunity of inspecting the operation of the pneumatic signals of the Union Switch and Signal Company. They have not been in operation for a sufficient length of time for the accumulation of the data necessary to a complete discussion of their performance. In the absence of a continuous record, the following interesting communication from Mr. Childs, General Superintendent of the Walkill Valley Railroad Company is given, as indicating the general performance of the signals.

ELECTRIC SIGNAL REPORT.

SECOND DIVISION P. & W. R. R., DISTANCE 39 MILES.)

From November 19, 1883, to October 1, 1884

The sm... ...es in the spaces, indicate the number of failures; the large ones, the number of trains stopped

Total	
4	Train or car on side track too near main
473	P. & W. trains stopped by P. & W. trains in section
16	Trains stopped by unknown trains in section
6	Trains stopped by hand cars in section.
19	Trains stopped by switch open in section.
	Trains stopped by switching at Valley Falls,
	Trains stopped by switching at Lonsdale.
33	Trains stopped by switching at Woonsocket.
42	Trains stopped by switching at Waterford
1	Trains stopped by switching at Quinsigamond.
5	Trains stopped by switching at South Worcester Yard

Total			Trains.
5	Broken rails	stopped	12
7	Switch boxes out of order	"	**10**
58	Lights out	"	**76**
	Failures on account of loose track wires	"	
4	Failures on account of broken track wires	"	4
46	Failures of machine	"	87
	Failures on account of weak current	"	
3	Failures of battery	"	7
6	Failures on account of track insulators giving out	"	9
19	Failures on account of machines run down	"	37
21	Failures on account of carelessness of employes	"	**31**
10	Failures on account of broken or crossed line or ground wires	"	19
3	Failures for which no cause was found	"	3
3	Brass springs rusting	"	5
1	Water in post, chain frozen,	"	1
1	Door loose, ice on chain,	"	2
12	Relay damaged by lightning	"	13
1	Repairing track	"	2
1	Switch frame worked away from plunger of switch box	"	2
1	Run down by hand car	"	1

99 failures, not including lights out or carelessness, stopped 165 trains

...horse-power engines located ...
of the line which is covered with the block signals.

Total
Total

Total
30
Total
th

Total
m
Total
1c

Perce

565 t
3c

Total

Perce

165 t
1c

Total
m

Perce

Total
si

T

of the pneumatic signals of the Union Switch and Signal Company. They have not been in operation for a sufficient length of time for the accumulation of the data necessary to a complete discussion of their performance. In the absence of a continuous record, the following interesting communication from Mr. Childs, General Superintendent of the Walkill Valley Railroad Company is given, as indicating the general performance of the signals.

NEW YORK, ONTARIO AND WESTERN RAILWAY COMPANY.

Walkill Valley Railroad Company.

General Superintendent's Office, No. 24 State Street.

J. E. CHILDS, *General Superintendent.*

NEW YORK, November 13, 1884.

THOMAS W. SPENCER, C. E., *Inspector for Board of Railroad Commissioners, of the State of New York, Utica, N. Y.*

Dear Sir:—I am in receipt of your favor of November 11th, and take pleasure in giving you information in relation to the electric and pneumatic signals.

These signals, as you are aware, are located upon thirteen miles of the West Shore Road, immediately south of Cornwall, which is operated by this company under a long lease.

This portion of the track used by the West Shore and Ontario and Western Companies, lies along the foot of Dunderberg, Storm King, Cro' Nest, and other mountainous regions of the highlands of the Hudson, where the rocky cliffs on the one side and the very deep water on the other necessitates many sharp curves. In some cases the water in the river was ninety feet deep, only twenty feet from the shore with bottom of shelving rock, where we were unable, to make an embankment, and were obliged in several instances to put in long spans of iron bridges. We also have on this thirteen miles two jack-knife draw-bridges, one Cantilever bridge, one tunnel, and the sharpest curves upon the road.

It was considered advisable on account of these objectionable features of this portion of the line, to place upon it the best system of automatic signals that could be found. Mr. George Westinghouse, of Pittsburg, having just procured letters-patent, upon his automatic, electric and pneumatic block signals, we arranged with him to equip this thirteen miles of the line.

The power used for compressing the air is furnished by two ten horse-power engines located near either extremity of that portion of the line which is covered with the block signals.

The air, after being compressed, is passed through coils of pipe and two cylinders where it is cooled, after which it is sent through a pipe one inch in diameter which is laid between the tracks. At intervals of three-fourths of a mile we have established semaphore signals for each track. These signals are located at points, where

they can be seen for the greatest distance, and are connected by a pipe with the main air pipe lying between the tracks. The signals are operated by compressed air cylinders, the valves of which are controlled by electric currents, one of which passes over the line on telegraph poles and the other through the rails. The signals are controlled by short circuiting electric current in the rails when a train or engine passes over the track, the current passing through the wheels and axles from rail to rail. Opposite each semaphore signal is a battery well built of brick below the surface of the ground, and contains for each semaphore signal a seven jar battery.

When a train passes into the block, the signal immediately behind the train shows both arms at a horizontal position by day, and two red lights by night; this is called an absolute danger signal; or the second "danger" position. The second signal from the rear of the train shows the upper arm in an inclined and the lower arm in a horizontal position by day, and a red and white light by night; this is called the first danger position.

You will see by this system that when one train follows within one mile and a-half of another, they are warned that a train is preceding them and the first appearance of the signal not only indicates danger, but absolutely locates it; for instance, if the engineer sees a signal with the upper arm inclined and the lower arm horizontal, or showing a red and white light, he knows that a train is ahead of him, but that the block immediately ahead of this signal is clear and that the train or obstruction is upon the second block. If he sees a signal with both arms projecting in a horizontal position, or showing two red lights, he knows that the danger is imminent and that the train or obstruction of some nature is upon the block ahead of this signal.

I enclose a book of instructions to employés, which, without describing the details of the signals at all, gives them all the information which they require and shows the simplicity of the system.

In addition to this, we have every switch upon this portion of the line interlocked with the circuit in the track in such a manner that whenever the switch is opened two danger signals are shown upon the main track from which the switch is turned. The electric current also passes into the rails of the side tracks out to the clearance distance, so that should a car, standing on the side track, be moved by malicious persons, or should it be blown by the wind to a point

where it might interfere with the traffic, two danger signals are immediately placed automatically on the track in the direction from which trains approach.

We also have two draw-bridges which are connected with this system in the following manner: The two jack-knife bridges on this portion of the line are connected with this system without changing the form of the automatic signals, two of them being made to act as distance and home signals for the draw-bridge. When a train approaches within 8,000 feet of the bridge, an electric bell is sounded continuously directly over the head of the watchman who attends to the draw-bridge, warning him that the train is approaching and that he must not open the draw. This bell rings from the time the train passes over a point 8,000 feet until it passes a point 7,000 feet from the draw-bridge when the gong ceases to sound. If, during the time the train is running from the 8,000 feet to the 7,000 feet point, the watchman should, contrary to instructions, undertake to open the draw-bridge, he cannot do so without first setting two danger signals in the face of the train while the train is still one and one-half miles distant from the bridge. After the train has passed over the point 7,000 feet from the draw-bridge, the draw-bridge is locked by electricity and cannot be opened. As these draw-bridges are on double track the signals operate in the same manner for both directions.

This I consider a very perfect system for the protection of a draw-bridge, and I could only suggest one improvement, which we are now considering; that is, to have a switch near the draw-bridge which shall throw the train off the track rather than let it into the draw in case the engineer disregards the signals.

We also have some crossings protected by electric bells, which ring at the crossing when a train approaches from either direction within one mile, and the bell continues to ring until the train has passed the crossing.

We also have, aside from the block system, an electric tunnel block signal, protecting trains while passing through Haverstraw Tunnel, which works automatically. When a train reaches a point within 2,000 feet of the tunnel, by short circuiting an electric current in the track, a danger signal is set in the rear of the train, which remains at "danger" and prohibits other trains from entering the tunnel until this train has passed entirely through, and 2,000

feet beyond the tunnel, when the signal goes to "safety," and the track is clear for following trains.

I have kept an accurate account of all failures which have occurred upon the line, and have sent copies of monthly report to the General Manager of the Union Switch and Signal Company, of Pittsburg, and am assured by him that the percentage of failures is much less than upon any other systems of signals that has ever been invented.

Enclosed I send you a copy of report of failures of the signals for the month of October. During this period 1,065 trains passed over this portion of the line. There are in all forty-five signals, including the home and distance signals for the draw-bridges, making 47,925 signal movements during the month. From the attached report, you will see that the total number of failures during this period were, including October 28th, when a break occurred in the main pipe at Fort Montgomery, which set all signals at danger, was sixty-eight failures, or about one-seventh of one per cent.

Report of Failure of Automatic Semaphore Signals on New York, Ontario and Western Railway Company, Hudson River Division, October, 1884.

Date.	*Number of Semaphore.*	*Nature and Cause of Fault.*	*Position of Blade.*
1	37 and 39	Broken battery jar.	Danger.
2	36	Weak battery.	Danger.
10	1, 9, 15, 17	Broken battery jar.	Danger.
14	19	Weak battery.	Danger.
17	7 and 9	Broken guard rail	Danger.
17	18 and 20	Track wires out of rail, on Iona Island trestle.	Danger.
18	23	Broken jar.	Danger.
20	25 and 27	Broken jar, leak in main pipe caused by slack union.	Danger.
24	36	Broken jar.	Danger.
26	9, 9 and 11	Weak battery.	Danger.
26	27	Spike between cross-over rails at West Point.	Danger.
27	9	Signal would not go to danger; armature screwed down, could not open.	Safety.
28	all	Break in main pipe at Fort. Montgomery.	Danger.
31	12 and 14	Weak battery.	Danger.

(Signed) G. W. BRADLEY, *Supt. Hudson River Div.*

To J. E. CHILDS, *General Superintendent.*

You will observe that, with only one exception, the signals went to danger, and consequently caused no harm, other than a slight delay to traffic.

These signals have been in operation since April 1, 1884, and in that time but two failures of the signals where they were at safety, and should have indicated danger, have been reported.

You will also observe that a number of failures occurred through broken battery jars. We find these jars were too light, and are now substituting heavier ones.

You have no doubt seen reported in the papers that an engine ran into Popolopen (? Ed. Com.) draw-bridge, in the month of October. This was not through any failure of the signals, as the engineer admitted having passed the distance signal 7,000 feet, and a home signal 650 feet from the draw, both set at danger.

From experiments recently made, I believe that this thirteen miles of automatic block signals can be operated with one engine if located at a point about the centre of the system, and I shall make the change in a few weeks, which will reduce the cost of operating the signals.

I shall be glad to furnish you any other information on the subject at any time. Yours truly,

(Signed) J. E. Childs, *General Supt.*

The HALL SYSTEM.

The only road completely equipped with this system is the New York and New Haven Railroad. In view of the fact that the order of the superintendent of this road, that no engineers shall in any case enter a section until a safety signal is shown, is an iron-clad rule, whose violation is immediately followed by removal, the inference may be fairly drawn that the mechanism of this system is very perfect and very certain in its action. Inasmuch as an official statement of the observance of this rule would add greatly to public confidence in the value of the system, a letter of inquiry was addressed to Hon. Geo. H. Watrous, President of the road. In reply, the following communication was received:

OFFICE OF NEW YORK, NEW HAVEN & HARTFORD RAILROAD COMPANY.

NEW YORK, February 7, 1885.

HON. GEORGE H. WATROUS, *President, etc., New York.*

Dear Sir:—In reply to yours, asking for report of the performances of the Hall's Signals, now in service on New York Division, I would say: They have never failed to perform their service; that is, they never have failed to show danger when they should.

The principle in their construction is such that, if the battery is not kept up, or if the wire breaks, or any of the mechanical parts give out, the signal will immediately go to "danger," and will remain so until it is attended to; the normal condition of the signal being danger.

It is the electric current that holds the signal up clear.

Since the signals have been in operation on the New York Division, we have had trains stopped on account of signal showing danger (when there was no train in the section ahead) from the following causes:

Weak battery, 18 times;	Stuck spindle, 5 times;
Broken wire, 3 times;	Loose connection, once;
Broken levers, 3 times;	Wires crossed, 4 times;
Weak spring, 3 times;	No cause given, 3 times.

Below please find answers to the questions which Mr. Rogers asks in his letter to you, and which you desire me to answer.

Question First: "Do the signals ever indicate 'safety' when they should indicate 'danger,' and under what circumstances or conditions?"

Answer: No; the signals *cannot* show "safety" when they should indicate "danger." When a train has set the signal, it cannot be cleared until that train has passed out of the section, running over the release, or cleared by the agent at the station.

In explanation, I would say, that there is a key in the ticket office, at the station where the signals are located, which allows the agent to clear the

signal, after it has been set by a train passing over it, and that train (instead of going beyond the station and running over the release) stops and goes in on a turn-out at the station. When the train is in on a turn-out all clear, the conductor reports to the agent, and he can then clear the signal to let another train come along.

Question Second: "As a matter of railroad economy, is the operation of the signals so nearly perfect, that you can afford to enforce the iron-clad rule of absolutely forbidding the entrance into a section until the signal passes from 'danger' to 'safety'?"

Answer: Yes, that is just what we are doing. No train is allowed to pass a signal when it shows red, without orders to do so.

In explanation of this I would say, if a train reaches a signal and it shows red, the train stops.

After the train has remained there ten minutes and the signal does not clear, it indicates either that the signal does not work, or else something has happened to the train that is ahead in the section.

Under these circumstances, when the train that is stopped by the red signal, has remained there ten minutes, it is then (as required by our rules) ten minutes behind the preceding train.

The conductor then has orders to send his brakeman ahead with a red flag, and after he has been gone five minutes, he can allow his train to follow, running very slowly (not over five miles per hour), until the next station is reached. There the train stops, and the conductor goes to the station telegraph office and reports to the Superintendent.

If there is no train ahead of him in the section, it shows that the signal is not working. He then receives orders from the Superintendent to proceed, and the station agent receives orders to put a green disc in that signal case, which indicates that the signal is out of order and trains can proceed through that section very cautiously.

In conclusion, I would say that, since the signals have been placed upon the road, I have watched them closely. There has never been any failure, so far as I know, in their working. As I said before, if anything happens to the wire, or the current is destroyed, or the mechanical parts need renewing, the signal immediately goes to "danger" as it should; *but the signal cannot show "clear" when it should show "danger,"* and I would feel perfectly safe with the Hall Signal, knowing that if they were used over the entire length of our road as a block system, one train could not possibly be in the section with another train, at the same time, if the signal was obeyed.

Respectfully yours,

WILLIAM H. STEVENSON,

Superintendent.

This positive testimony in favor of the Hall system would seem to indicate that it is well adapted to meet the complicated requirements of a great railroad. The improvement over the old Hall, or open circuit system, is very marked. It should be said,

however, that the old Hall system is still in successful operation on the Worcester Division of the Boston and Albany Railroad. Daily and monthly reports of the operation of these signals are made up in the office of the engineer of the road, showing results, which though not equal to those obtained under the Union Switch and Signal Co.'s system at the Boston end of the road, are however, quite satisfactory. In illustration of the great improvement which has been made since the introduction of electric signals, the following reports are extracted from the Report of the the Board of Railroad Commissioners of Massachusetts for 1880, pp. 210, 211.

REPORTS ON THE OPERATIONS OF ELECTRIC SIGNALS.

Boston & Albany Railroad Company,
Boston, December 13, 1879.

Dear Sir:—In reply to your questions concerning the Hall Signals, I send you a comparative statement for the years ending November 30, 1878 and 1879. The whole number of stops made by trains in 1879, caused by other trains in the section, was 1,689. Stops made for cause unknown, 1,573. So far as we can tell, these stops were unnecessary. The number of signals not working is 4,344. In these cases caution would be indicated, and the danger signal would not be shown to a following train, during the time the preceding train was in that section. We continue our rules for guarding the rear of trains, and do not rely upon the signals at any time. Connected with switches and bells at highway crossings, the system works very very well. There are 39 signals east of South Framingham which are operated 2,748 times daily (Sundays excepted), and 350 times on Sunday.*

Yours respectfully,

W. H. Barnes.

D. W. Lincoln, Esq., *President Boston and Albany Railroad.*

Comparative Statement of the Working of Hall's Signals for the Year Ending November 30, 1878 and 1879.

	1878.	*1879.*
Trains stopped by another train in section, .	1,612	1,689
Trains stopped, cause unknown, . . .	624	1,573
Failed to work, ...	2,800	4,344

* The product of the number of signals, multiplied by the number of trains passing and acting on them during the year, is 878,324, and is the number of times requiring the movement of a signal; so that the number of reported failures to act—4,344—is one in 202 times.—*Commissioners*.

EASTERN RAILROAD COMPANY,
BOSTON, December 22, 1879.

W. A. CRAFTS, Esq., *Clerk Board Railroad Commissioners.*

Dear Sir:—In reply to your inquiry for information in regard to the working of our automatic signals during the past year, I will give the following information:

As you will recollect, I made a report on 12th of August, in which was briefly described the working of our modified Hall system, with a list of its failures during a period of some months.

Since that date the operation has been still more satisfactory; as, for instance, in November, when, from approach of winter, an increased number of failures might naturally be expected. The following are the facts:

Whole number of stops during month, 27.

CAUSES.

Spindles stuck,	8
Wires crossed,	3
Section men moving material,	1
Trains in section,	15
	27

On the whole, while the system is not perfect, it has given very fair satisfaction, and is a great help to the safe and economical working of the road. Up to the present time know of nothing better.

Yours truly,

E. B. PHILLIPS,
President.

FITCHBURG RAILROAD,
BOSTON, MASS., Dec. 12, 1879.

Hon. THOMAS RUSSELL, *R. R. Commissioner, No. 7 Pemberton Square, Boston.*

Dear Sir:—Your favor of the 8th inst., addressed to the President, in relation to the Union Electric Signal Company's signals in use on this road, has been referred to me.

Please find enclosed herewith a tabulated statement, which I have had prepared for you from the reports rendered by the enginemen, showing the number of times the signals have been found at danger, and the causes, from May 1 to November 15, 1879, inclusive.

The total number of regular week-day trains, which have passed over the larger portion of the signals, during the period covered by this statement, is 12,312; and the number of extra trains, shifting engines, etc., is undoubtedly half as many more, making the total number of week-day trains 18,468, which is an average of 108 trains per week-day.

We think they are a success, and that they add materially to the safety of the trains. An important feature in this system is, that, if it fails to operate, it cannot endanger the trains.

For further information in regard to them, I would refer you to my communication of August 15th last, addressed to your Board in response to inquiries upon the subject, as the facts remain substantially unchanged.*

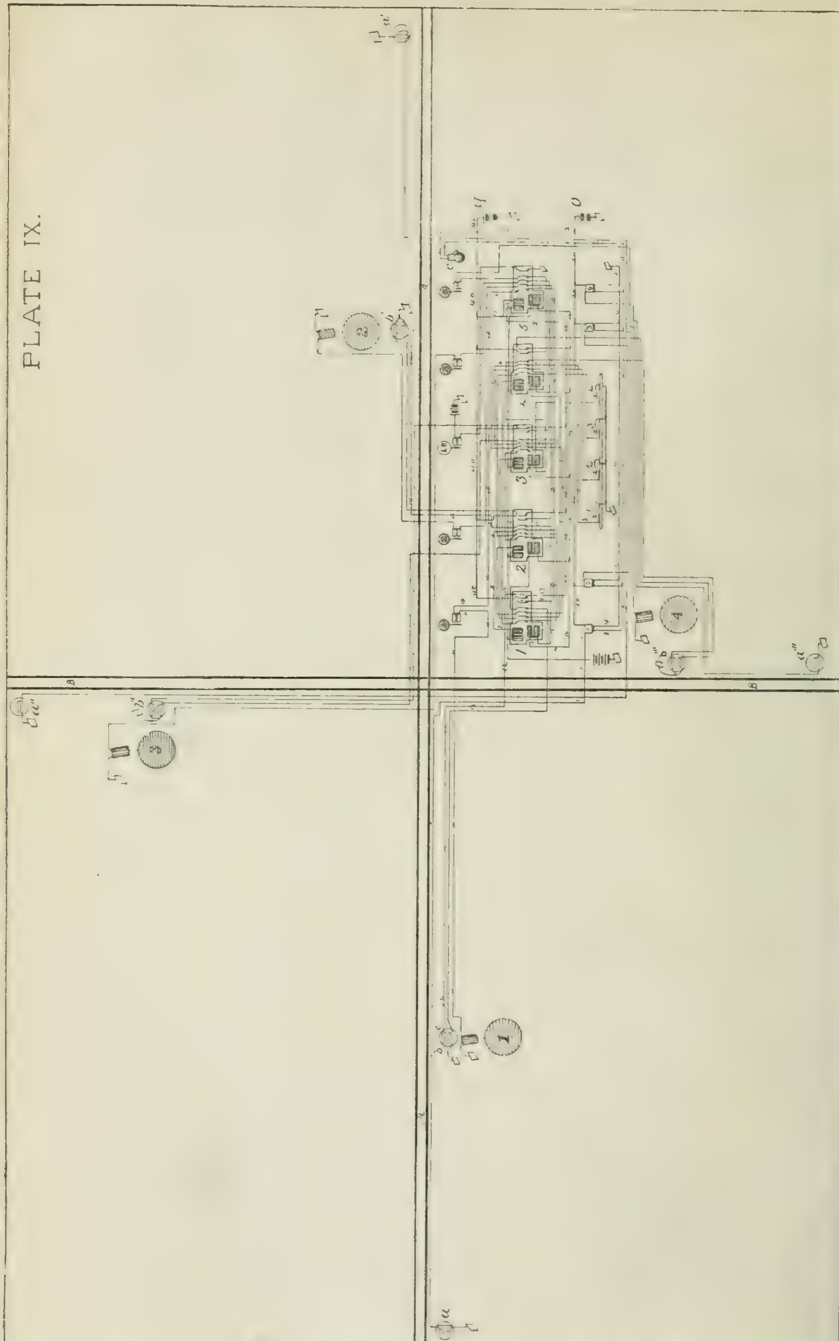
Respectfully, JOHN ADAMS,
General Superintendent.

Tabulated Statement of Reports in regard to Electric Signals found at Danger on the Fitchburg Railroad, from May 1 to November 15, 1879, inclusive.

MONTHS.	Train in Section.	Broken Rail.	Hand-car in Section.	Misplaced Switch.	Trackmen Working in Section.	Cause not known.	Signal Wires, etc., being out of Order.	Interruptions caused otherwise than by Trackmen.
1879.								
May,	24	.	1	1	1	1	7	. .
June,	19	. .	1	3	. .	2	16	. .
July,	12	. .	1	2	9	11	27	
August,	1	. .	. .	. .	. .	6	26	1
September,	7	. .	6	1	1	5	35	. .
October,	2	. .	. .	1	1	4	26	2
November to the 15th inst.,	. .	. .	. .	. .	2	. .	14	. .
	65	. .	9	8	14	29	151	3

* The number of signals is thirteen.

PLATE IX.



The RAILWAY CAB ELECTRIC SIGNAL COMPANY.

This system is in use in this country only upon the Staten Island Railroad. At the time of the inspection already referred to, it had been in operation about four weeks. According to the report of the engineer of the train, there had at that time been no failure.

The system was first tested in Austria. The company offers the following testimony of its successful operation there:

[*Translated Copy.*]

IMPERIAL ROYAL DIRECTION OF THE STATE RAILROADS OF AUSTRIA IN VIENNA.

No. $\frac{66}{11}$. VIENNA, February 24, 1884.

The Honorable, Sir Thomas C. Miles, Colonel and Adjutant:

In reference to your honored favor of January 19th, I honor myself to communicate to you the following: The experimental section is situated beyond Purkersdorf, where the Putnam signal system is being tested; to prove, first, the insulation of the rails, and, second, the sure and continued sounding of the whistle signal on moving trains, which has been operated since October 14, 1883. From this date, October 14th, to the end of December, 1883, the locomotive provided with the signal machinery ran sixty-three times. In two cases the function failed, namely, on November 10th and December 24th, in consequence of disturbances in the dynamo machine; while in sixty-one cases the apparatus acted normally. The tests will be continued and further results communicated to the Honorable Sir.

The First President,

(Signed) CZEDIK.

[*Translated Copy.*]

IMPERIAL ROYAL DIRECTION OF THE STATE RAILROADS OF AUSTRIA IN VIENNA.

No. $\frac{66}{11}$. VIENNA, May 8, 1884.

The Honorable, Sir Thomas C. Miles, Colonel and General Manager:

In answer to your favor of March 23d, I honor myself by communicating to you that the failures in the operation of the Putnam signal alarm apparatus in the section of experiment near Kellerwiese, which took place November 10th and December 24th, of last year, and mentioned in the letters $\frac{66}{11}$, according to the investigation made on this subject, were called forth by defects in the mechanism on the locomotive, and not by the constructive principle of the Putnam system.

For the Imperial Royal Director,

(Signed) SIEGEL.

[*Translated Copy.*]

IMPERIAL ROYAL DIRECTION OF THE STATE RAILROADS OF AUSTRIA IN VIENNA.

No. $\frac{3981}{11}$. VIENNA, July 1, 1884.

The Honorable, Sir Thomas C. Miles, Colonel and Adjutant:

In answer to your esteemed letter of June 18th, I honor myself by communicating to you in reference to my letter, No. $\frac{66}{11}$, dated February 24, 1884, that the locomotive equipped with the Putnam signal system machinery, has run on the section near to the station Kellerwiese, 244 times, from the first of January to the last day of May, and the alarm apparatus has operated normally, with the exception of two cases. These two cases occurred on the 31st of January and 10th of April, and the cause of the first case was the tearing of the wire of connection between the locomotive and the tender; in the second case, by the magnet becoming loosened.

The First President,

(Signed) CZEDIK.

Extracts from a voluminous report of the Imperial Royal Austrian State Railways, made at Vienna, December 5, 1884:

This engine has passed over the insulated points near Kellerwiese from October 15, 1883, to August 21, 1884—350 times, and in these 350 trips the apparatus has failed to operate, that is, the steam whistle has not blown, five times. These five failures occurred on the following dates—November 10, December 24, 1883, and January 31, April 10, and July 6, 1884. The first failure was owing to the fact that the armature did not fall on account of a bent screw, the second was due to the failure of the steam valve; the three other failures were caused by the breaking of the wire between engine and tender. As far as the introduction of an automatic system of railroad signals may be considered desirable, it must be admitted that the Putnam system is far ahead of any other.

In conclusion, the following report of Mr. Kintner is added as an independent estimate of the three systems of signals offered for examination. The objections noted in my examination are nearly identical with those enumerated by Mr. Kintner. It will be sufficient, therefore, to refer to his report:

NOTES OF C. J. KINTNER UPON EXHIBITS OF RAILWAY SIGNALS.

OCTOBER 3, 1884.

PROFESSOR W. B. ROGERS.

Dear Sir:—In conformity to your verbal request of the 2d inst. to the effect that the Sub-Committee on Railroad Signals, of which you are Chairman, should offer individual suggestions upon which to base your report, I beg to offer the following:

The exhibits are :

(1.) The Putnam Cab Company.

(2.) The Hall Signal Company.

(3.) The Union Switch and Signal Company.

Taking them in the order named, I will pass upon them as follows :

The Cab signal embraces :

(1.) A block signal system.

(2.) A road crossing signal system and gate.

(3.) A misplaced switch and bridge.

The desirable features, which make it particularly valuable, are :

(*1.*) Audible signals are given of the condition of the track crossings, etc., on board the locomotive by a trembler bell, which warns the engineer by ringing that danger is imminent. This feature is valuable in itself, in view of the many accidents which occur through color blindness, and where night signals are set. It is sure of action (provided the electrical circuits are carefully secured) in all kinds of weather, foggy, rainy or during blinding snow. These features commend the system. The block arrangement appears to be effectual, and so far as I can ascertain, very certain in its action. I think with properly insulated circuits, there can be no question as to the efficiency of this system. The drop gates also deserve commendable mention for the simplicity and ease of action, thus rendering road crossings more secure against a dangerous class of accident. I think this feature deserves especial notice in behalf of the public welfare.

The operation of the signaling electro-magnetic apparatus by a dynamo, driven by an engine on the locomotive, is also a very desirable feature, rendering the signals independent of batteries, which are uncertain in their action and troublesome to keep in working order. As to the advisability of independent conductors apart from the rail, as before indicated, perfect insulation and secure fastenings for the wires should be used to render them free from mishaps due to weather and track walkers.

This system is based solely on Putnam's patents.

It is to be noted further that there are no mechanical signal arms, operated by mechanism, liable to get out of order, a very essential element, I take it, in any such apparatus. With this mechanism, as in all devices where positive action is demanded, unvarying in its actions from time to time, this is a very desirable feature.

As to demerits, there is, in my opinion, one essential element lacking, viz. : a means of showing the condition of the track on intervening portions of the sections, such as broken rails, a car blown or run by accident from a siding on to the main track. These features must enter into the discussion, and are, in my opinion, all-important in a system upon the accuracy of whose action lives and property depend. Nor does this system adapt itself for railroad crossings in the nature of blocking the egress and ingress of trains within limits of the crossings.

(*2.*) *The Hall Signal Company.*

This system embraces :

(1.) Block signals.

(2.) Switch signals.

(3.) Railroad crossings.

Aërial or insulated conductors are used independent of the rails. The road divided into sections has three signals dependent upon each other, so that an incoming train sets the signal near at hand at "danger," releases the rear signal at the rear end of the section from which it is passing, and sets it to "safety;" sets the distant advance signal to danger, and all are connected by interlocking mechanism, such that only a proper progress of the train actuates the signals in their order. The system is undoubtedly a good one, very positive in its action, works well, and has been in action, I am advised, on several railroads, where it gives satisfaction.

I doubt whether the vertically-swinging signal is a good one in any system, inasmuch as there is too much strain upon the parts where levers have to be used to raise an arm from vertical to horizontal, and mechanism acting in such a manner is liable to get out of repair. There is the further objection to such systems, that there must be absolute attention given to winding up the signaling actuating mechanism, to repairing the parts, and oiling the bearings, restoring the batteries, etc., etc. I point out these features to show wherein the audible signal excels the visual, inasmuch as the mechanism is much simpler. These suggestions have their bearing on the question of general efficiency.

As to the railroad crossing signal in Hall's system, I can say its action is all that could be desired, and the interlocking of the signals, so that trains cannot approach a crossing, without violating orders, until a safety signal is given, deserves mention.

Hall also shows a very desirable, slow-moving circuit closer, for action when the train is under full speed, which is accurate in its action and deserves mention. I refer to the rubber-cushioned lever, with piston attachment. It will not easily get out of repair.

The apparatus for moving a misplaced switch is quite positive in its action, and appears to be an effectual apparatus.

My objections to the system are:

(1.) Uncertainty of contact by mechanical circuit closer may occasionally render the signals inoperative.

(2.) Mechanism for raising and lowering signals requires more than a minimum attention.

(3.) Batteries require attention and are uncertain.

Advantages are in the security offered by causing each signal to control both the advance and rear signals automatically and keep them displayed until the next succeeding section is reached. This company work under Hall's patent exclusively.

(*3.*) *The Union Switch and Signal Company.*

This company work under the patents of Pope, Gassett, Robinson, Fisher, Westinghouse and others, and their system embraces an aggregation of the several features disclosed in these patents.

The main features embraced in their system are as follows:

(1.) Block system.

(2.) Railroad crossing block.

(3.) Misplaced switch.

(4.) Controlling switches from signal-man house pneumatically.

(5.) Audible signal at road crossing during the short period prior to and after passing said road.

(6.) Derailment of train at a railroad crossing, if the engineer fails to stop in time after a danger signal is displayed.

(7.) Broken rail indicated on entering the section.

(8.) Pneumatic controlling apparatus for actuating the switch and signals.

The system, as a whole, is quite complex; but the mechanism appears to be of substantial nature and quite positive in its action.

The advantages appear to be:

(1.) That in the use of the rails for conveying the electricity, a positive index is placed upon the rails themselves for indicating a break or rupture at any point within each section, and for indicating if a car has been blown from a siding upon the main track.

(2.) A misplaced switch is for a like reason indicated.

(3.) The blocking is made doubly secure by being so simple in the action that by a train backing off a section, the signals are all set at "danger," both in the rear and in advance.

(4.) The constantly ringing safety bell before and after passing a road crossing are decidedly desirable attachments.

(5.) The pneumatic apparatus is simple and decidedly positive in its action. As to liability to get out of repair by wear of packing, leakage, etc., I should think there might be such a liability.

(6.) The derailment of a train at a crossing I can hardly commend, it being questionable whether it is better to endanger the lives of passengers by a certain accident in view of a probable accident.

(7.) The horizontal swinging signals known as the Gassett and Fisher signal used by this company are much simpler, and mechanically much easier to actuate than the vertical or arm signal, and by their swinging vanes attract attention. Respectfully submitted.

C. J. KINTNER,

Sub. Com. on R. R. Signals.

ELECTRIC TIME SIGNALIZER.

This apparatus is intended for purposes where time signals are required ; automatically securing precision of time in the moving of visual signals, sounding of bells, or production of the various mechanical movements desired in the warning and departure of railway trains, street cars, ferry boats, or where schedule time is required.

To effect this object, a mechanism is employed, which consists of a clock having a dial of an insulating substance, divided into twenty-four divisions, representing two series of twelve hours each. denoting the divisions of the day, and subdivided into minutes, and a hand or pointer carrying mechanism for changes of schedule.

There are also placed concentrically on the dial, metal rings denoting the divisions of time, with slots and contact points. The body of the pointer has within it a rotating shaft, making one revolution in seven days, which has on it a calendar cylinder denoting the days of the week, and discs containing contact pins, which are placed over their respective rings and contact points, which, at designated times, make an electric contact, closing the circuit, within which circuit are signaling bells, gongs, semaphores or other calling, warning or mechanical device.

Any number of electric circuits with any number of rings can be opened and closed by the pointer and its attachments.

On Saturday, at midnight, it automatically changes for the Sunday schedule, and resumes week-day work at midnight of Sunday.

A swift moving minute hand can be employed, to show minutes and seconds, if desired.

Changes from summer to winter schedule can be made in a few minutes.

The signals can be made on a bell or bells of any size, at any distance from apparatus. The apparatus can be used in any large school, where a number of class-rooms exist, and if required, different calls may be made for each day of the week.

A small apparatus with a single or double belt, would answer for all ordinary work.

In case the time-table cannot be carried out, owing to obstructions or other causes, a convenient switch cuts out the particular belt or belts, and a hand push-button would then be used, until the time-table can be restored, when the apparatus will take charge. The buttons can also be used for extras or specials.

REPORT OF SUB-COMMITTEE ON METEOROLOGICAL AND OTHER REGISTERS.

PROFESSOR M. N. HARRINGTON, *Chairman.*

CUSHING'S VELOCIMETER.

This is an adaptation of Morse's printing machine to the purpose of measuring high velocities. On a ribbon of chemical paper, press three electric pens, which leave a trace on the paper when the current passes through them, and none when the current is broken. The paper is unrolled by a hand crank, and kept properly taut by suitable appliances. Of the three circuits, one passes through a vibrating piece of metal in such a way that the circuit is made and broken at each vibration. The time of vibration being ascertained, this serves as a convenient and sufficiently accurate time measurer, each beat leaving its mark on the prepared paper. Of the other two circuits, one is broken at the beginning of the record, the other at the end.

The special excellencies of the velocimeter, claimed by the inventor, are:

(1.) Its extreme simplicity. It can be handled by a non-expert after a few minutes' instruction; there is no mechanism to get out of order, and no part of the instrument that, in case of breakage, cannot be repaired at small cost.

(2.) Its absolute accuracy and precision. The instrument exhibited will measure the $\frac{1}{1500}$th part of a second, but a reed could be used that would give a measurement as small as the $\frac{1}{5000}$th part of a second.

(3.) Its portability. There are only two small instruments in the system, and they can be packed in a box fifteen inches cube, and easily transported.

(4.) It makes a record of all observations, that may be filed away for future reference, a feature, I think, possessed by no other velocity measuring device.

This principle of recording small periods of time can be adapted to timing horse races, measuring the speed of ships at sea, measuring the velocity of sound, etc.

The apparatus was tried in measuring the speed of a rifle ball, and its working was entirely satisfactory. The instrument is undoubtedly accurate, simple, and very portable, and we can commend it highly.

ELECTRO-PNEUMATIC VALVE.

The Milwaukee Electric Manufacturing Company, of Milwaukee, Wis., manufacturers of electrical specialties, exhibited the Johnson electro-pneumatic valve, in its applications for controlling steam and air passages, of which the following is their description:

The novelty of this invention broadly consists in the application of a fluid under pressure as a motive force for operating valves or passages for fluids, the fluid under pressure being electrically controlled, *i. e.*, an expansible chamber is mechanically attached to a main valve; the fluid under pressure is admitted and

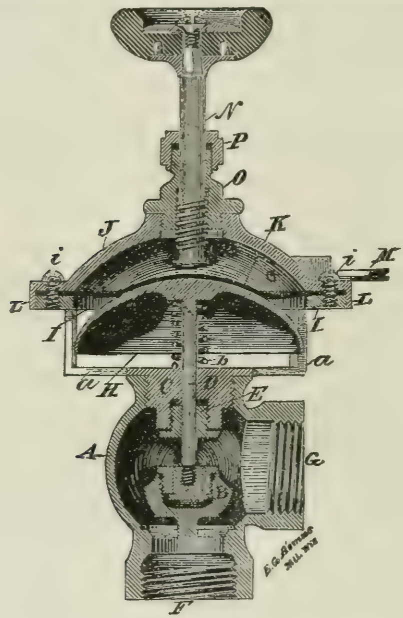


FIG. 23.

released from the expansible chamber, thereby actuating the main valve, the admission to and release of the fluid from the expansible chamber being electrically controlled. In order to make the actual construction of the apparatus more clearly understood, reference is made to the accompanying sectional view of an angle valve as actually constructed. (*See Fig. 23.*)

A is the chamber of the main valve, *F* being the inlet and *G* the outlet orifice. *B* is the valve disc, which closes downward upon its seat, thereby closing the passage. The stem *D* of the

disc is furnished at its opposite and external extremity with an inverted saucer *H*. The valve is held normally open by the steel spring *b*, placed between the saucer *H* and the plug *C*. External leakage is prevented by the stuffing box *E*, through which the stem *D* plays vertically.

Supported by the standards *a a* is the concave metallic cap *J*. Stretched across the under side of this cap, from *L* to *L*, is the flexible *K*. By means of a number of screws, as *i i*, the periphery of the diaphragm *K* is held tightly against the cap *J*, thus making an air-tight chamber between *K* and *J*. It is evident that if a fluid under pressure is admitted into this chamber through the tube *M*, that the valve *B* will be pushed downwards to its seat.

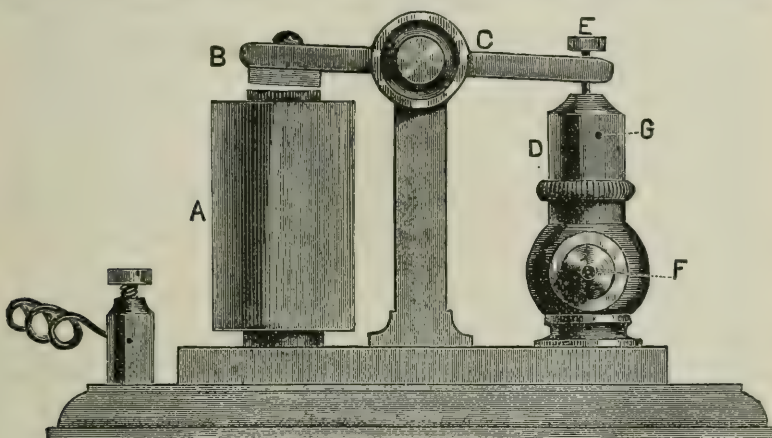


FIG. 24.

The force with which the valve *B* is seated will, of course, be proportioned to the area of the diaphragm *K*, pressure to unit of area remaining constant, the total force exerted at any time being the product of pressure per unit of area into the total area. In the valves shown, the proportional area of the diaphragm *K* to the area of the valve *B* is as 13 to 1, so that a fluid of less than ten pounds pressure admitted to the expansible chamber will properly actuate a main valve driving against 100 pounds pressure per unit of area.

The electrical mechanism used to admit and release the fluid from the expansible chamber is shown in the above cut, which represents a side elevation.

A is an electro-magnet; *B* its armature; *C* a lever adapted to raise the rod *E*, when the circuit is closed through *A*. Within *D* is the mechanism for the admission and release of the fluid under pressure from the expansible chamber, shown in *Fig. 24*. This mechanism may be termed a frictionless three-way cock. When the circuit is completed, the fluid is admitted to the expansible chamber, but its release prevented. When the circuit is broken the ingress of the fluid under pressure is prevented and its egress is permitted. *F* shows the ingress port and *G* the egress port.

In the apparatus, as shown, the diameter of the opening in this secondary valve was $\frac{3}{100}$ths of one inch, and its lift was $\frac{4}{100}$ths of an inch, although even less would be sufficient. When air or other gas is used as the fluid under pressure, these dimensions are found amply sufficient, unless rapidity of action in the main valve is required when these dimensions are increased. From the smallness of area of secondary valve and its frictionless character, it will be seen that the electrical energy required to operate it is very small. Practically, one cell of gravity setting is found to be amply sufficient. The size of the secondary valve is not changed, although the primary valve be very large and worked under high pressures.

As actually shown, the fluid under pressure used was air. The apparatus exhibited consisted of a steam radiator for heating rooms, and having the diaphragm valve attached. A thermostat in the room controlled the electric circuit and thus the supply of steam. By this mutual reaction of the temperature and steam supply the temperature of the room remains constant. A large butterfly valve (eighteen inches in diameter), attached to an air flue, was also exhibited. This, likewise, was actuated by the thermal conditions of the room. Upon the boiler plant of the exhibition was placed a large whistle, actuated by this device. It is blown by touching a button in the superintendent's office. Other uses of this invention are included, such as the controlling of refrigerating machinery, steam pumps, elevators, rudders, etc.

This instrument was examined in its working and found to be entirely satisfactory. When the electric valve is used to control temperature a thermostat is employed. It consists of a thin long plate of hard rubber, and a similar one of steel, the two fastened together the entire length. The compound plate, thus made, is

fixed at one end while the other plays between two contacts which admit of easy setting within a narrow range. With a rise or fall of temperature, the thermostat curls and makes the contact, thus completing the circuit, on one side or the other, and regulates the valve. We found by experiment that the thermostat was quite sensitive and that the claim of the owners that the temperature could be controlled to a quarter of a degree each side of the setting point could probably be realized. We think, however, without having tested it, that the hard rubber plate of the thermostat would not work so well at high or low temperatures, as at the middle temperatures (65°—75°), but for housewarming and similar purposes, there will be no occasion to expose the instrument to such temperatures. The action of the thermostat is also quick. We reduced it from 64·5° to 32° in eight minutes.

The AUTOMATIC ELECTRIC HEAT REGULATOR.

MANUFACTURED BY THE PERFECT HATCHER COMPANY, ELMIRA, N. Y.

(F. ROSEBROOK, INVENTOR.)

The owners claim in their heat regulator, the combination of a double electric current, the electro-magnet, damper, door or valve, and suitable mechanism for operating dampers and valves.

The object of this invention is to provide means of regulating and controlling heating apparatus of any and every description, not only controlling the source of the heat, such as the combustion of coal, lamp flames, etc., but will also control the flow of the heat to different points. It consists of:

(1.) A thermostat, as shown in the accompanying cut on the left. This instrument is exceedingly delicate and sensitive, and will register the tenth part of a degree if so desired; this is hung in the room or apartment to be regulated, or controlled. If a room in a dwelling house, it can be placed on the wall in any convenient spot.

(2.) The motor connected with a damper or valve, as shown on right. This motor as shown, is a spring motor, but it can be of any form desired, or can be used in connection with a larger motive-power, such as water pressure, compressed air, etc. The essential object of this motor is to enable us to use two electric circuits, one to open the dampers and one to close the same, whereby we have a constantly open circuit, and a single cell will last in constant use for a year or more, with no other attention than to renew the water. This motor is provided with a circuit breaker (as shown at *T, U, V, Fig. 25.*), which breaks the circuit at a different point than the point of contact, the connecting wires across each other thereby keeping the surfaces always bright. No matter how much dust and dirt accumulate on this breaker, it never fails to respond promptly.

Any number of valves or dampers can be attached to this motor with proper increase of power.

(3.) The battery switch connecting wires.

Fig. 25 shows the thermostat on the left, and clock and valve on the right. The thermostat is hung on the walls of any of the rooms, as shown at *A, Fig. 26.* The clock-work and valve is placed on a branch of the smoke pipe of the furnace, as shown in *Fig. 26.* The electric jar is shown at *C*, in *Fig. 26.* The operation is

as follows: One must first decide upon what heat is most desirable, the majority prefer 72, others 68, 70, or even 80. Then move the pointer, *Fig. 27*, to the desired degree, as shown on the scale. For instance, if 70 is desired, move it to figure 70. The draft will be checked at 70 and put on again at 69, as the thermostatic bar is set for one degree variation, and is exceedingly sensitive to every variation of the heat; it is perfectly accurate, and responds to the variation more quickly than mercury. It is a compound bar of rubber and steel riveted tightly together. As the heat of the room rises, the unequal expansion of the two substances produces a

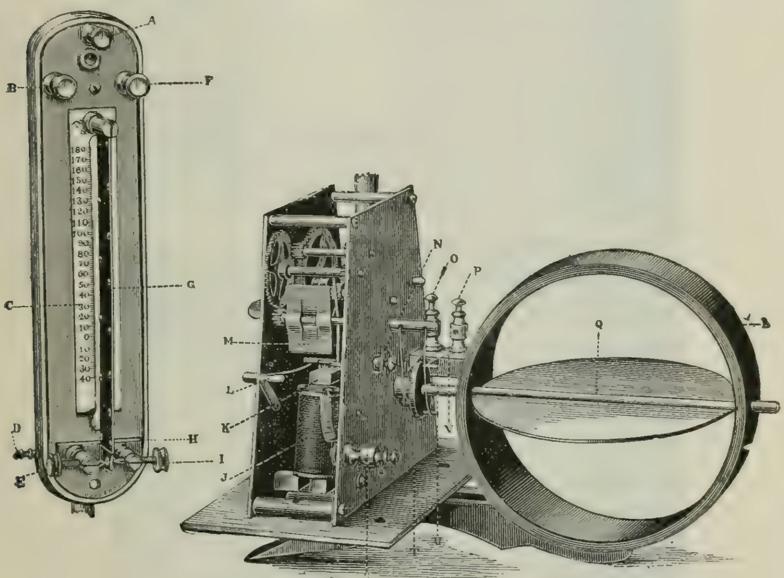


FIG. 25.

lateral motion, and the free end of the bar moves over to the screen *E*, and comes in contact with it, the electric circuit is closed. This sets the clock-work in motion, and the valve *F*, *Fig. 26*, opens, and the draft of the furnace is checked; the chimney, now drawing through this opening in the pipe, instead of through the furnace. Combustion of the coal practically ceases, and temperature moderately declines one degree and brings the bar *B* in contact with screw *F*. It is, therefore, easily understood that if the weather gets colder, more heat is required from the furnace, and the thermostat will not check the draft, until the heat is up to the right point, but

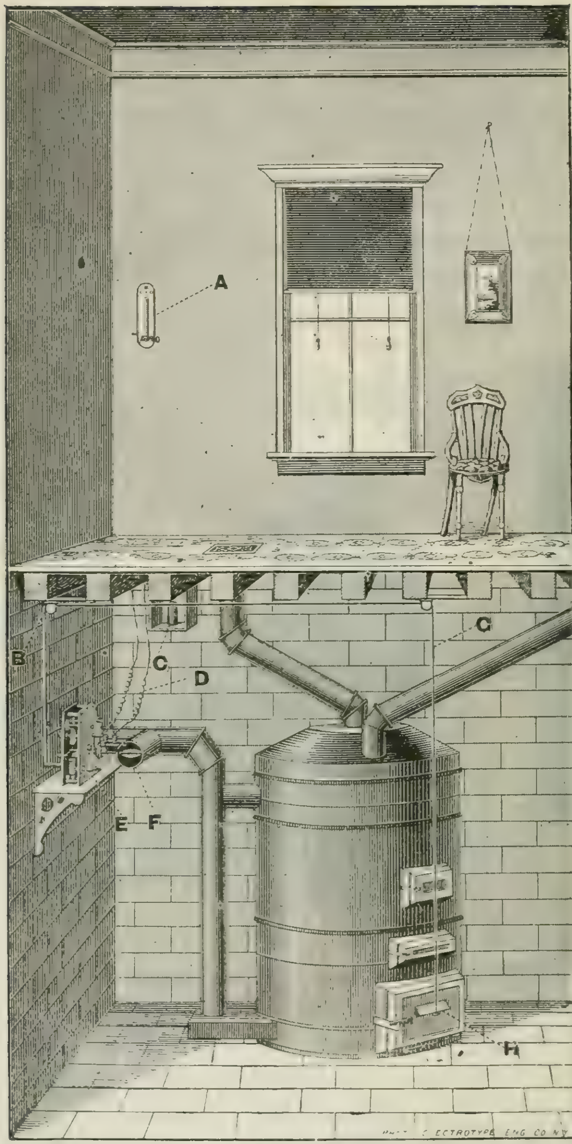


FIG. 26

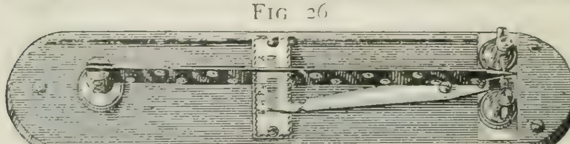
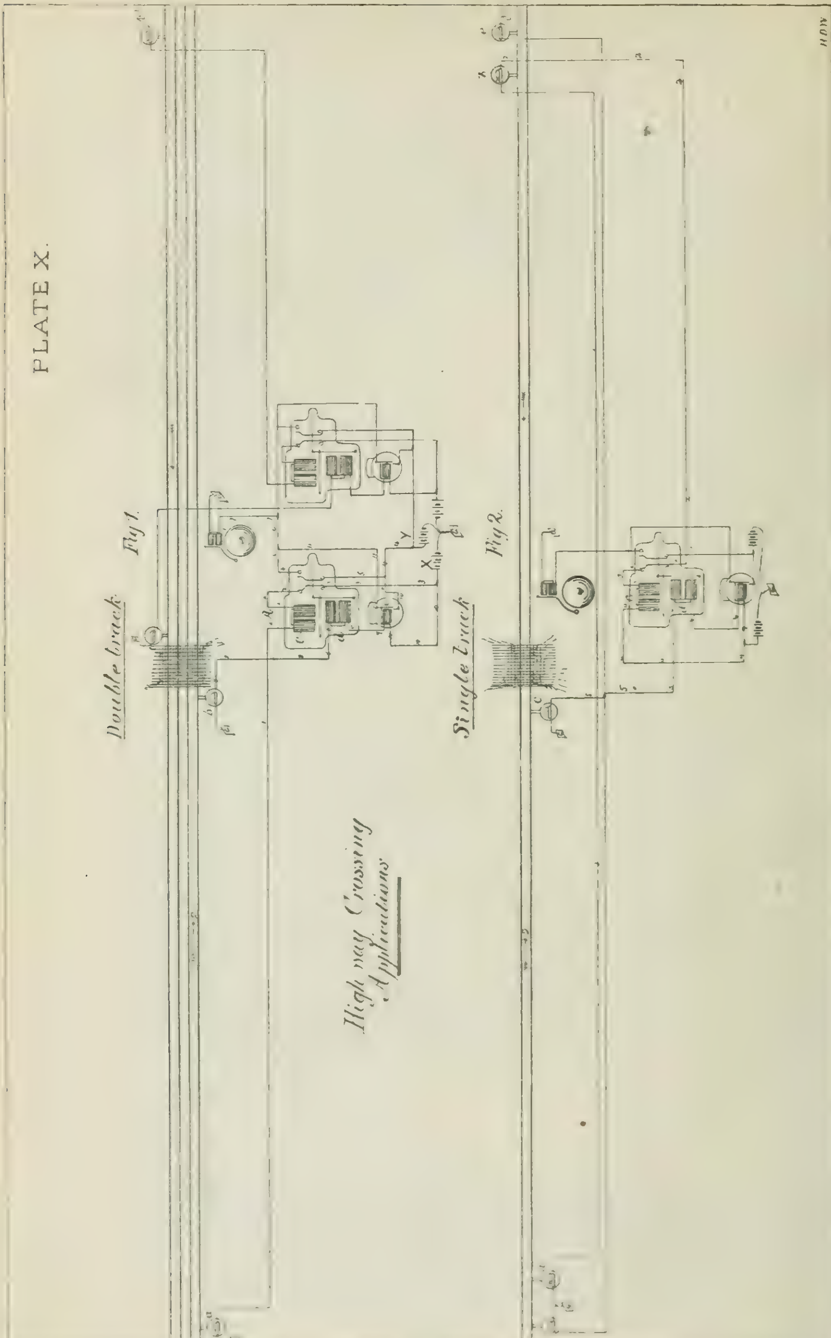


FIG. 27.

PLATE X.


Double track
Fig 1.
Single track
Fig 2.
Highway Crossing Applications

will drive it as hard as is necessary to keep the heat up, and per contra, if the weather grows warmer, the thermostat will hold the furnace in check and keep the heat down to the required point, thus checking all extra consumption and waste of coal; every pound of coal that is burned to raise the heat higher than is required, is wasted. It has been proven by actual experience in the past few years, that twenty-five per cent. of coal has been saved since adopting this regulator. The temperature can be changed instantly to any point desired by simply moving the pointer, *Fig. 27*, to the figure on the scale desired.

This regulator can be put to numerous uses, chief of which is its application to an incubator of the same makers, in which the motor operates a ventilator, in connection with the source of heat as well. In this case, the thermostat is altered and consists of a rubber rod stationary at one end, and connected with a lever delicately hung at the other, as the heat rises, this rod expands, throws the lever to one contact point, connecting a circuit, operating valves and lamps as the heat of the machine requires.

The above is part of the description of the instrument as made by the owners. The apparatus was of considerable interest, and some features of it deserve especial commendation. One of the thermostats is similar to that described in the preceding instrument, and has similar advantages and disadvantages. As in the preceding case, it is entirely suitable for any work likely to be required of it. The other thermostat is a rubber rod, by the expansion and contraction of which the necessary motive-power for the regulation of the valves is obtained. The character of its working can be judged from the study of the distribution of temperature in the incubator upon which Prof. Waldo is to report.

The contact breaker in this instrument deserves commendation. The contact is made on sliding surfaces, and the points of contact are thus kept smooth and bright.

STEAM VESSEL INDICATOR.

NOVELTY ELECTRIC WORKS, PHILADELPHIA.

This instrument is intended to inform the occupants of the pilot house of the position of the throttle and reversing levers in the engine-room. It consists (*Fig. 28*) of two parts, viz : indicator and switches. The indicator proper, which is hung in pilot house has two electro-magnets and double armature, to which is attached

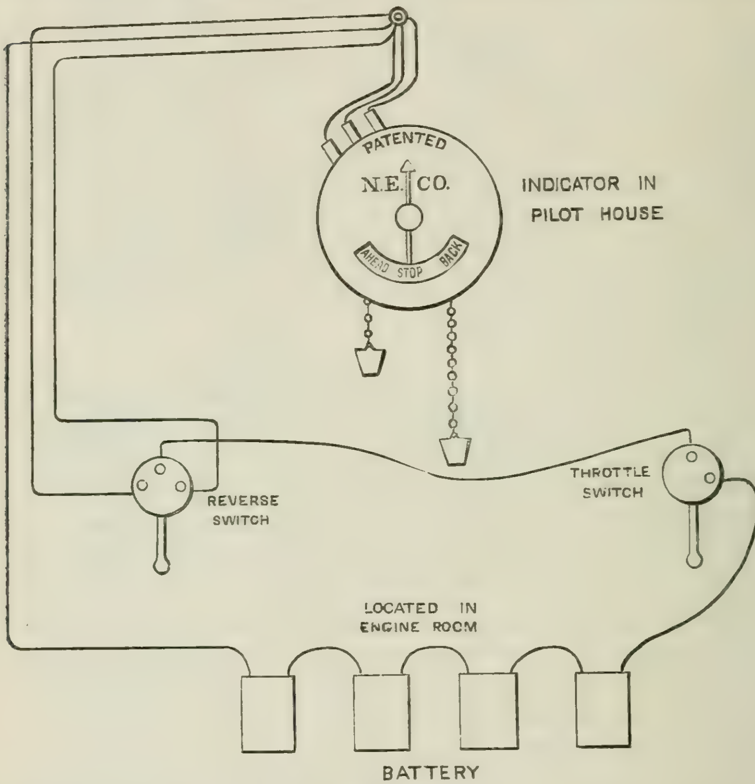


FIG. 28.

the indicating hand. As the current is thrown first through one magnet, and then the other, the needle indicates ahead or back. When the current is cut off, the needle points to "stop." The current is sent through one magnet or the other by means of the switches, which are connected to the levers of the engine; one to the throttle, the other to the reverse. The mode of operation is very simple, consequently reliable When the pilot rings the bell

to move, the moment the engineer touches the lever of the engine, it shows in the pilot house which way the reverse lever is standing, as the current must flow through one of the two magnets. When the engineer reverses the engine, he cuts the electric current from one magnet and causes it to flow through the other, thus causing the armature to be attracted one way or the other, indicating either ahead or back. The starting lever starts the electric current.

The reversing lever shows which way the engine will move. The general relations of the parts are shown in the accompanying diagram. When not required, the circuit can be opened and so left until again required, the change from open to closed being made in the pilot house by the cords suspended from the dial. The circuit is also broken when both levers are undisturbed, in which case the index swings by its own weight to the mark "stop." A bell is connected with one circuit, so that the position of the engine levers is also distinguished by the ear. The indicator seems to be effective and reliable.

TELEMETERS.

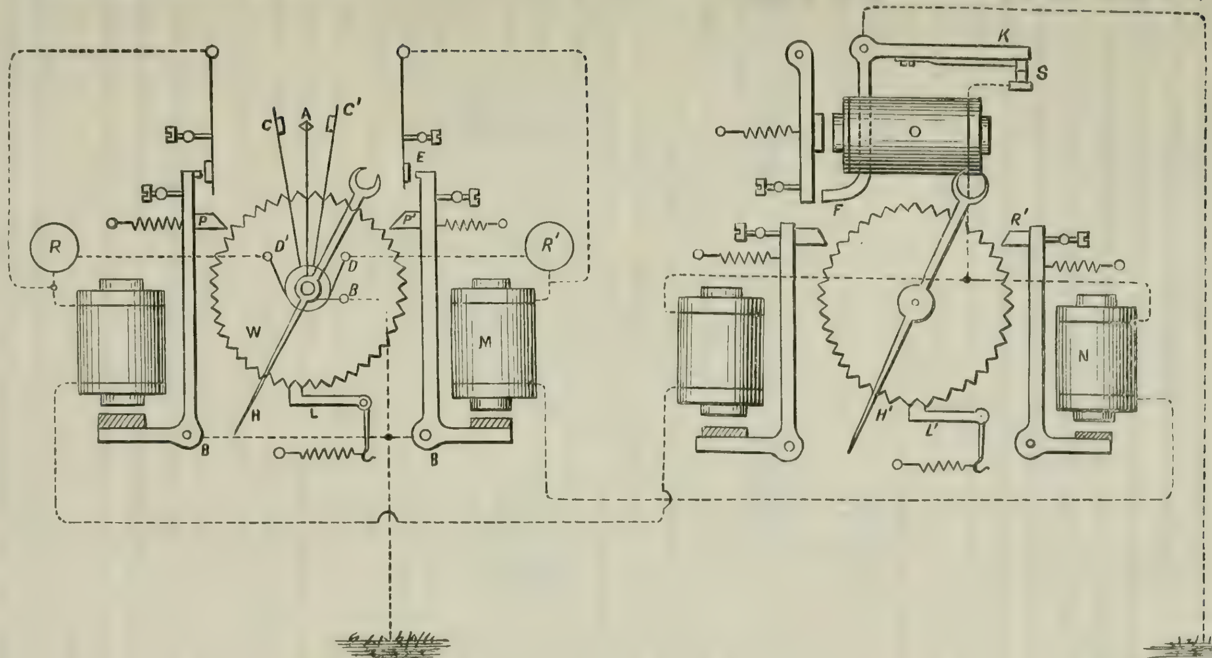
THE TELEMETER COMPANY, NEW YORK CITY.

This is a complete and novel system of transmitting and recording physical changes at a distance and continuously. As exhibited, the system was applied to temperature and atmospheric, steam and water pressure, but the system admits of indefinitely extended application. The Telemeter Company attributes the system to Robert Hewitt, Jr., as originator, and to Charles L. Clarke, as inventor.

The novel part of the system is the transmitting device and receiver. The following description of them is Mr. Clarke's: (*See Plate XII.*)

The transmitting device is at the left hand, and receiver at the right hand.

The contact arm A is on a shaft, and is moved by the initial physical instrument, be it metallic thermometer, barometer, pressure gauge, float or other device. It is not insulated from the metal frame of the instrument, and is therefore connected (electrically) to the *base*, as are also the armature levers. This fact is shown diagramatically at B B B, and by the circuit connecting the three points. C C' are two contact points carried on arms, which are carried on an insulated sleeve, and also insulated from each other. This sleeve is carried on a shaft (which also carries the **V**-toothed wheel W) which is in line with the shaft carrying A. As W revolves with C C', the continuity of the circuit is preserved by two insulated posts, D D', which carry two wires resting in two grooves in the insulated sleeve, thus maintaining the circuit of D with C, and D' with C', respectively. The shaft carrying W, C C' also carries the index hand H. P P' are the pawls which propel the wheel W, are normally out of the path of its teeth, the wheel being held by the locking pawl $<$. When P advances, it engages at tooth near its point, and pushes it ahead until the pawl rests in the space between the teeth which it fits. In this position, the under face of the pawl is a tangent to the circle of which the pivot on which the armature lever revolves in the centre. Hence, the face of the tooth pushes dead against the centre, and no force such as the momentum of the wheel, resulting from the force of the blow given by the pawl, can disengage the pawl. Therefore, no matter what the excess of battery-power, the wheel can never be



System of the Telemeter Company.

revolved the distance of more than one tooth by a single impulse, and the whole constitutes a complete locking device. When the pawl P has reached the limit of its forward movement, the pawl $<$ has slipped over the point of its next tooth, so that when P is withdrawn it $<$ slips into the space and completes the motion of the wheel, which is the amount of one tooth. The wheel and pawls of the receiver are similar to those of the transmitter, hence if both instruments receive a full impulse, sufficient to carry P to its forward limit, they must move in unison, as neither wheel can move more than a tooth for a single impulse. When A is moved by a force and touches C, the magnets N, N, O are in circuit, as also the small resistance coil R'. N is so adjusted that it attracts its armature first. The first movement of its armature causes a contact at E, which forms a shunt around resistance R' and contact A C. The continued motion of the armature causes P' to engage a tooth and to turn the wheel W until P' fits in the space between the teeth, thus locking the wheel, and separating the contact A C, the pawl $<$ also slipping over the point of its next tooth. The circuit has not been broken, because a shunt was formed around A C before they were separated. They were also separated without a spark, because they formed a branch circuit with R' resistance to a shunt with no resistance. Simultaneously, or nearly so, with the engagement of P', the pawl R' in the receiver also engages the wheel, and the operation last described is repeated here. The magnet O is adjusted to respond last in the series, and the movement of its armature lever strikes the arm F, thus throwing up the horizontal arm F, and breaking the circuit at S. The instant that S is opened, the spring draws the armature levers back to their normal position, separating the points at S, and since A C are already open, when S closes again on its return stroke, the circuit is open and remains so until A makes another contact. Also the return of the armature levers disengages P' and R', and permits $<$ $<'$ to complete the movement of one tooth, and H H' have moved one division on the dial. The spark is all transferred from the delicate contacts to the rough, large, non-adjustable contact S.

It is impossible for H H' to move except in unison, because any current will first firmly close the circuit at R, and the circuit cannot open until O operates, and this is adjusted to work last.

To prevent S from opening at the wrong time (which it could do from a mechanical jar or shock, thus, perhaps, opening after H had moved, and before the movement of H', thus throwing the hands H H, out of unison) the point S carried by K is supported on a long spring, which is so adjusted that when K is raised S is held about $\frac{1}{14}$th inch from K, but when K is down S presses against it. Thus, any jar which may raise E less than $\frac{1}{14}$th inch does not cause S to break the contact. (*See Fig. 29.*)

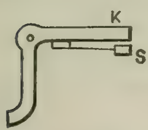


FIG. 29.

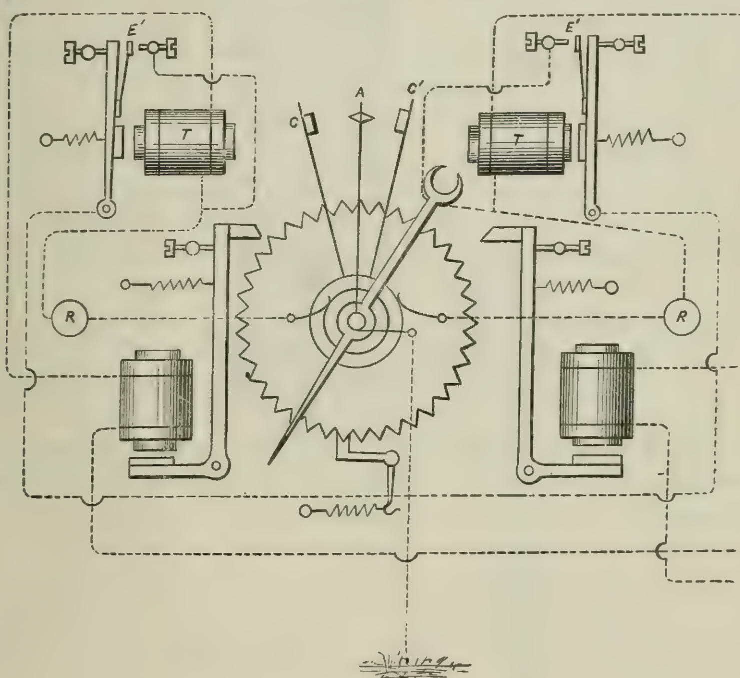


FIG. 30.

Under date of September 26th, Mr. Clare presented a slight modification of the apparatus, with a transmitter, in which the shunting around the primary contacts A C C' is accomplished by magnets T T at E' E'. The latter method presents some advantages over the preceding. (*See Fig. 30.*)

The actuating instrument for the telethermometer is a metallic thermometer made by the Standard Thermometer Co. of Pea-

body, Mass. In accompanying *Fig. 31*, the base plate *A* carries a port *B* through which passes a stud *C*, which is fastened firmly by a set screw *D*. The stud *C* supports an arm, and to it is rigidly attached one end of the bi-metallic spiral *G G* by the set screw *F*.

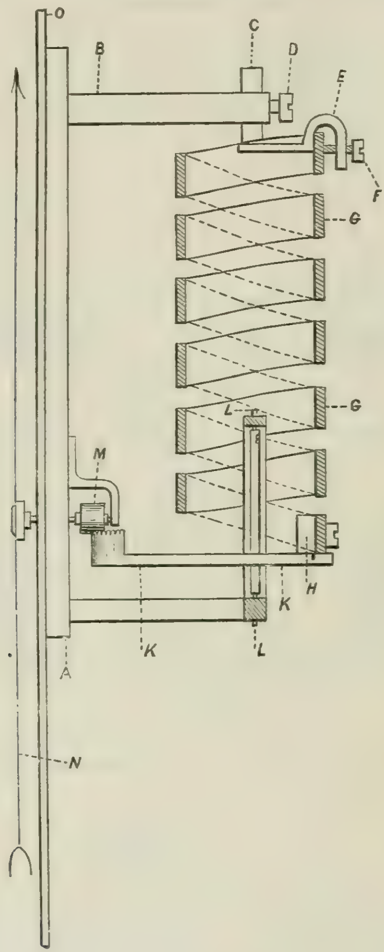


FIG. 31.

The range of the thermometer is adjusted by changing the length of *G* as chamfered on *E*. The spiral *G* is made of two metals, having different coefficients of expansion. One end is fixed at *E*, and the other end is free to move as the rise or fall of temperature lengthen or shorten the spiral circumferentially. The end free to

move is attached at H to a segment of a crown wheel KK. KK revolves on its bearings LL, and moves the pinion, M, carrying the index arm or pointer N in front of a graduated dial O, indicating upon this dial the temperature which affects the spiral GG.

The work which can be got from a metallic thermometer well constructed, is of considerable interest, and the sub-committee made a special test of some of the instruments provided by the Telemeter Company. The test was under Dr. Waldo's direction and his report will follow.*

The telemanometer is actuated by a Bourdon tube; the telehydrobarometer by a wheel and float on a mercury column balanced by water pressure. The telebarometer is actuated by a wheel and float in the open arm of a siphon barometer of large diameter, to prevent error from capillarity. The telemeter instruments are recording, the paper being moved by clock-work. Maximum and minimum alarm hands are also provided, which may be set at will to ring an electric bell at any desired limits. By the use of a polarized relay and batteries of opposite polarity, one wire connecting the two instruments may be dispensed with.

The committee examined this exhibit with interest and attention. The general system is good, and the minor intrinsic difficulties have been successfully overcome by the inventor.

---

* These thermometers have since been studied by Professor Rogers, who published his results in the *Am. Meteorological Journal*, Vol. II., pp. 252–257.
H.

REPORT OF SUB-COMMITTEE ON TIME-PIECES.

EXHIBIT OF THE TIME TELEGRAPH COMPANY, OF NEW YORK.

This company had a large exhibit, which was scattered over the buildings. The particulars to which they wished to call especial attention were as follows, as made out by Mr. H. L. Bailey, their electrician :

(1.) An electrical pendulum regulator. The pendulum of which is subject to uniform impulses, with a minimum of friction or variation, the electrical contacts of which are absolutely certain in their performance, and at which there is a complete suppression of spark, while operating the circuit, the latter being accomplished by placing a non-inductive shunt of fifty ohms resistance around magnets of ten ohms resistance in the circuit. The perfection of the driving anchor, which corresponds to the escapement of non-electric clocks. The ratchet wheel, which prevents any backward movement of the scape wheel.

The device by which the train effects the contacts for minute and second dials, whereby the pendulum suffers no disturbance, and notice taken of the fact that variation of friction in the train, or variations in the strength of the actuating current, uniformity of action, and its adaptability to the purpose for which it is used.

(2.) A system of sparkless circuit closers for the operation of secondary electrical clocks or other electrical devices. Its operation depending upon the automatic introduction of shunt around the magnetic circuit, before opening the battery circuit.

(3.) Secondary electric clocks. One known as Crane's dial movement, in which the driven wheel is perfectly locked in either open or closed circuit. It is simple and perfectly reliable in its action.

(4.) Secondary electric clock, "Gray's dial" with its double motion, first radial then tangential, also thoroughly reliable in its performance.

(5.) Exhibit of three or four other dial movements, controlled by the Time Telegraph Company.

(6.) A table half-second pendulum clock, device of C. H. Pond.

(7.) A system of synchronizing pendulums, without any harness being applied to the pendulum of the primary regulator, but, making use of the electrical seconds, furnished by the rocking armature table of the electric regulator.

The requirements of the Time Telegraph Company and the engagements of the committee necessitated putting this examination in the hands of Professors Rogers and Harrington. The exhibition was not a suitable place for critical tests of such delicate mechanisms; such tests require also considerable time; the sub-committee therefore decided to, in some sort, integrate the entire system by directing attention to the actual time keeping capacity of the system and of the controlling clock. This was done by sealing the various accessible secondaries, and leaving them so for several days, and also by comparing the controlling clock with time received from Washington. These tests were begun by the two members of the committee, but completed by Prof. Rogers, whose report is incorporated here:

REPORT ON THE PERFORMANCE OF THE STANDARD ELECTRIC CLOCK, EXHIBITED BY THE TIME TELEGRAPH COMPANY.

The master clock, which controlled the dials exhibited by this company, was mounted upon a wooden pier, fairly insulated from the building. Two other clocks, of similar construction, were mounted upon the same pier, one of them being upon the opposite face.

It is still an open question whether an electric clock can be regarded as an instrument of precision, even when mounted under the most favorable conditions. It certainly was not to be expected that the performance of this clock should be exceptionally good, especially as there was a weaving loom in the space occupied by an adjacent exhibitor. It will be seen, however, that the clock maintained a nearly constant rate between October 4th and October 9th.

The comparisons with the clock at the central office, from which the Washington time is distributed, were made by means of a chronograph, kindly placed at my disposal by Capt. O. E. Michaelis, in charge of the exhibit of the War Department.

The sounder through which the time signals were received, was connected with the master clock in such a way that only eight or ten of the first seconds of each minute were given for the central clock, and only the beginning of each minute for the master clock.

In the transcript of the chronograph sheet given herewith, the long stroke, *a*, *b*, represents the beginning of the minute of the master clock, the initial point being at *a*. The beginning of the minute of the clock at the central station is indicated by the break *c* (*Fig 32*).

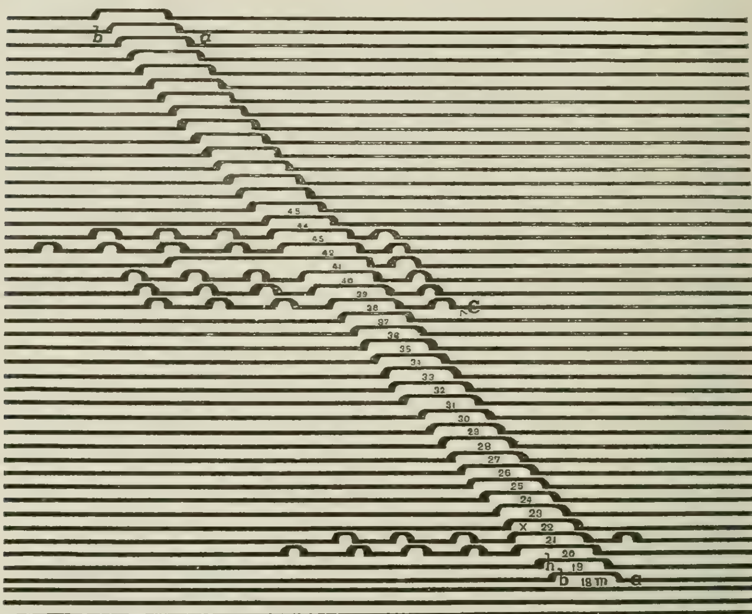


FIG. 32. Section of Chronograph Sheet, Comparison of Clocks.

The corrections of the Washington signals were kindly communicated by Lieut. C. C. Pendleton, of the Naval Observatory. These corrections combined with the observed deviations from the Washington signals at the central office, give the following corrections to the central clock at 12 *h*. M.:

October	s.	October	s.
4,	— 0·5	7,	— 1·6
5,	— 0·4	8,	— 1·6
6,	— 0·8	9,	— 1·8

Comparison of Master Clock with the Clock at Central Office :

October 4th. Master Clock Slow. *h. m.*	*s.*	*October 5th.* Master Clock Slow. *h. m.*	*s.*	*October 6th.* Master Clock Slow. *h. m.*	*s.*	*h. m.*	*s.*
12 36 P.M.	+ 0·63	6 46 A.M.	+ 0·57	6 47 A.M.	+ 0·45	8 3	+ 0·78
1 11	0·61	12 00 M.	0·55	7 40	0·49	9 45	0·90
2 18	0·64	1 00 P.M.	0·53	9 00	0·46	10 20	0·87
2 30	0·62	2 00	0·54	10 50	0·53	11 00	0·91
4 53	0·64	3 00	0·57	11 27	0·54		———
1 38	0·65	5 00	0·58	12 22 P.M.	0·54		+ 0·66
9 42	0·62	7 00	0·58	5 56	0·68		— ·80
	———	9 00	0·54	6 22	0·69		———
	+ 0·63	10 45	0·57	6 41	0·71		— ·14
	— 0·50		———				
	———		+ 0·56				
	+ 0·13		— 0·40				
			+ 0·16				

October 7th. Master Clock Slow. *h. m.*	*s.*	*October 8th.* Master Clock Slow. *h. m.*	*s.*	*October 9th.* Master Clock Slow. *h. m.*	*s.*
6 50 A. M.	+ 1·54	7 10 A. M.	+ 1·86	7 10 A. M.	+ 1·86
8 10	+ 1·57	7 30	+ 1·88	9 45	+ 1·87
8 50	+ 1·54	9 47	+ 1·88	10 00	+ 1·88
1 00 P. M.	+ 1·55	2 30 P. M.	+ 1·89		———
2 30	+ 1·59		———		+ 1·87
5 50	+ 1·73		+ 1·88		— 1·80
6 15	+ 1·74		— 1·60		———
6 40	+ 1·77		———		+ ·07
7 00	+ 1·79		+ ·28		
7 40	+ 1·81				
8 00	+ 1·78				
8 30	+ 1·80				
	———				
	+ 1·68				
	— 1·60				
	———				
	+ ·08				

In tabulated form, the corrections of the master clock are nearly as follows, at 12 *h.* M.:

October	*s.*	*October*	*s.*
4,	+ 0·13	7,	+ 0·08
5,	+ 0·16	8,	+ 0·28
6,	— 0·14	9,	+ 0·07

Since the probable error of a single estimation of the deviation of the central clock from the Washington signals is at least, 0·2 *s.*, the resulting corrections for the master clock came out quite as small as one should expect. The slight increase of the correc-

tions shown by the afternoon comparisons are probably due to the tremors produced by the loom, which was then generally in operation.

The synchronism by which the three clocks maintained the same rate was in this instance more marked than the writer has ever before witnessed. At no time during the exhibition did they differ much in excess of 0·5 *s.* In order to be able to estimate the amount by which the master clock could be changed through synchronism, a weight of thirty-one grammes was added to the pendulum opposite the master clock at 10 *h.* 0 *m.*, October 9th. At this time the deviation of the master clock was 1·87 *s.*

The following relations were subsequently found :

Time of Comparison. *h.* *m.*	*Master Clock Slow of Central Clock.* *s.*
2 30	+2·20
3 30	2·40
4 30	2·52
6 50	2·54
7 20	2·52
9 00	2·46
10 00	2·52

At 10 *h.* 1 *m.* the added weight was removed. By the next morning, the error of the clock had been reduced to the previous value, 1·9 *s.* It is to be regretted that there was not sufficient time for a repetition of this interesting experiment. W. A. R.

On the Performance of the Electric Clock Exhibited, Controlled by the Master Clock

This clock was located about 200 feet from the master clock. Every comparison of the two clocks, made previous to October 4th, showed an exact coincidence within the limits of the error of comparison, which may perhaps have amounted to 0·2 *s.* At 4 *h.* 30 *m.* P. M., October 4th, the control was removed.

Subsequent comparisons gave :

Date. *October*	*Time.* *h.* *m.*	*Controlled Clock fast.* *s.*	*Reduced to 9 h. 20 m., Oct. 4th, with Hourly Change = ·962 s.* *s.*	*Sum.* *s.*
4,	9 20 P. M.	= — 4·0	+ 0·0	— 4·0
5,	9 20 A. M.	= — 16·2	+ 11·5	— 4·7
6,	7 00 A. M.	= — 36·4	+ 32·4	— 4·0
6,	4 50 P. M.	= — 46·8	+ 41·8	— 5·0
7,	5 43 P. M.	= — 69·8	+ 65·8	— 4·0

It appears, therefore, that the controlled clock maintained an approximately constant rate after the removal of the control. The clock was now set 1 *s.* slow. At the end of 18·2 hours, it had gained 18·8 *s.*, giving an hourly rate of 1·03 *s.* At 10 *h.* 5 *m.*, the magnet was held 18 *s.* leaving the clock 1·0 *s.* slow. October 9th, at 10 *h.* 44 *m.* A. M., the correction was 1·3 *s.* slow. It appears, therefore, from these observations that the control is practically perfect.

In order to determine the magnitude of the rate which could be overcome by the control, 92·4 grammes were added to the pendulum. The following comparisons were then made:

Date.	*Time.*		*Clock Slow of Master Clock.*	
October	*h.*	*m.*	*s.*	
9,	11	30 A. M.	1·1	
9,	12	15 A. M.	1·1	
9,	12	40 A. M.	0·8	At 2 *h.* 5 *m.* added 24 grammes.
9,	2	5 P. M.	0·8	At 2 *h.* 6 *m.* took off control.
9,	10	8 P. M.	28·5	Fast.

The hourly change, therefore, with the weight added, is 3·64 *s.*, giving 2·5 *s.* for the rate due to the weight alone.

It appears, therefore, that the control will overcome a gaining rate of about 3 *s.* per hour. Lack of time prevented further observations in this direction. W. A. R.

Report on the Performance of the Time Dials.

The somewhat laborious operation of sealing the dials by covering the faces with threads, sealed in such a manner as to effectually prevent their being opened by unauthorized persons, was completed under the direction of Professor Harrington during the afternoon of October 7th. The dials were examined twice each day till the close of the exhibition. On account of my absence on the closing day, the examination was kindly made by Professor J. Burkitt Webb.

The number of dials in the circuit was sixty. In justice to the exhibitor, it should be stated that it was not expected that the performance of two of this number would be satisfactory on account of their locations. One was located above the bridge, connecting the two buildings, and the other was placed in the headquarters of the Board of Examiners.

The former clock, upon one occasion, lost two seconds, and the latter stopped upon three occasions. Another dial stopped within

a few minutes after the trial had begun from some unknown cause. With these exceptions, the coincidence of beats was exact in every case when the seals were broken at the close of the exhibition.

W. A. R.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XI.

(*SECTION I, CLASS VI OF THE CATALOGUE.*)

STEAM ENGINES.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, FEBRUARY, 1886.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1886.

EDITING COMMITTEE.

PERSIFOR FRAZER, *Chairman*,
CHARLES BULLOCK,
THEO. D. RAND,
COLEMAN SELLERS,
WILLIAM H. WAHL.

1884-INTERNATIONAL ELECTRICAL EXHIBITION-1884

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XI.—STEAM ENGINES.

To the Board of Managers of the FRANKLIN INSTITUTE:

GENTLEMEN:—I have the honor to transmit herewith the report of Examiners of Section XI, on "Steam Engines."

Respectfully,

M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, November, 1885.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—I herewith hand you the report of Section XI, on "Steam Engines."

Respectfully,

WM. D. MARKS.
Chairman Section XI.

REPORT OF EXAMINERS. SECTION XI. STEAM ENGINES.

Code of the Quantitative Tests Proposed for the Steam Engines, at the International Electrical Exhibition of 1884, of the FRANKLIN INSTITUTE, *of the State of Pennsylvania.*

SPECIAL NOTICE.

Parties exhibiting engines who may desire quantitative tests made of them, must make formal application for such tests before July 15, 1884.

Engines can be exhibited, but will not be tested unless formal application and agreement to the code are completed within the specified time.

Parties desiring to have tests made of their engines, can have them made by so signifying and by subscribing to and fulfilling the conditions of the Code.

All tests will be quantitative, and will not be abridged, save by special agreement with the judges.

Tests of regularity of speed will, however, be made independently of other measurements.

The Committee reserves the right to limit the number of engines tested, and to elect which engines shall be tested, if time will not permit complete tests of all.

Competitive tests will not be made, save on the joint application of the two or more parties desiring them, who must agree on the rating of the various points of the engines (See Article 9) previous to the tests, and subscribe in the Code, agreeing to abide by the decision of the Judges without appeal.

SECTION I.

CONDITIONS OF EXHIBITION AND TEST.

ARTICLE 1. Cylinders.

The cylinders of the engines entered may be of any capacity and proportion of stroke to diameter.

ARTICLE 2. Indicator Connections.

Each cylinder shall be drilled and tapped by the builder for indicator connections, by means of one-half inch pipe, in the usual manner, and to the satisfaction of the judges. Pet drainage cocks must be on the cylinder. The cross head, or other moving part, must be drilled for the indicator cord attachment.

ARTICLE 3. Clearance.

Each cylinder shall be drilled and plugged at both ends, so as to admit of being completely filled with water and emptied by means of a one-half inch pipe, in order to determine the clearance and the piston displacement of one stroke at each end. These data will be obtained both hot and cold.

ARTICLE 4. Valves.

The steam and exhaust valves will be tested under full steam pressure, ninety (90) pounds per square inch by the gauge, unless some other pressure has been agreed upon for the test.

ARTICLE 5. Piston Packing.

The tightness of the piston packing will be determined by removing the back cylinder heads, and subjecting the piston to full boiler pressure on each centre.

ARTICLE 6. Fly Wheel.

Each maker is requested to use such diameter of band fly wheel, or of pulley, as shall give a belt speed of 4,000 feet per minute.

Should he require a different belt speed, he will specially note the same in communicating with the Exhibition Committee.

ARTICLE 7. Steam Pipes.

Each exhibitor will be required to furnish his own connection with the main steam pipe, the main injection pipe, and the main overflow pipe or tanks.

ARTICLE 8. Space.

Each exhibitor will be furnished with space at the regular rates established for the Exhibition, in which space he must build his foundations at his own cost, and subject to the approval of the Superintendent.

ARTICLE 9. Specifications.

Each exhibitor will communicate to the Chairman of the Committee of Judges on Steam Engines, such description and drawings of the engine exhibited as will facilitate the labors of that Committee, together with his claims as to the meritorious points for his exhibit.

The Following Points will have Special Consideration.

(1.) Economy of steam.
(2.) Regularity of speed.
(3.) Concentration of power.
(4.) Durability of construction.
(5.) Simplicity of design.
(6.) Excellence of proportions.
(7.) Finish of parts.

Each exhibitor must file the following data:

Diameter of the steam cylinder to the nearest $\frac{1}{100}$ of an inch.
Diameter of the piston rod " " " " "
Diameter of the steam pipe " " " " "
Diameter of the exhaust pipe " " " " "
Diameter of the band, or fly wheel " " " " "
Width of the face, or fly wheel " " " " "
Weight of the fly wheel in pounds.
Area of the steam ports each to the nearest $\frac{1}{100}$ of an inch.
Area of the exhaust ports each " " " " "
Stroke of the engine " " " " "
Indicated horse-power of the engine when working most economically.
Revolutions of the crank per minute.
Weight of the whole engine, exclusive only of the fly wheel.

If a condenser is used and driven by the engine.

Diameter of the air-pumps to the nearest $\frac{1}{100}$ of an inch.

Diameter of the injection pipe " " " " "

Diameter of the overflow pipe " " " " "

Stroke of the air-pump piston " " " " "

If an independent condenser is used, that is not driven by the engine.

Diameter of the injection pipe, to the nearest $\frac{1}{100}$ of an inch.

Diameter of the overflow pipe " " " " "

Drawings of the condenser used, any other data peculiar to it, and a full description of it.

SECTION II.

PREPARATIONS FOR THE TEST.

ARTICLE 10. Steam.

The steam for the tests will be furnished by the exhibition boilers, and will come from boilers specially set apart for the purpose of the tests. It will be charged for at regular rate of three (3) cents per indicated horse-power per hour. Steam, if desired, will be furnished to exhibitors one week before the tests are made.

No charge will be made for the services of attendants or experts, or the use of apparatus, unless in some extraordinary case, when the cost will be fixed by the Superintendent of the Exhibition. No charge against the engine will be made for steam when its power is ordered by the Superintendent for the other purposes of the Exhibition.

ARTICLE 11. Pressure.

The steam pressure used will be subject to the wish of the exhibitor, but shall not exceed ninety (90) pounds per square inch, by the gauge.

A special standard gauge will be used during the test, and subjected to careful tests before and after use.

ARTICLE 12. Safety valve.

The safety valve will be set to blow off at ten (10) pounds above the pressure fixed upon.

ARTICLE 13. Quality of the Steam.

The thermal value, the temperature and the pressure will be taken by means of scale calorimeters, thermometers and standard gauges at the boiler, at the steam chest, and at the exhaust, if the engine is non-condensing.

The thermometers, calorimeters, etc., will be furnished by the Exhibition, but the exhibitor must do such mechanical work, must furnish such piping, tools and materials as are necessary to make the required attachments, at his own cost, and subject to the orders of the Committee of Judges.

ARTICLE 14. Temperature.

The temperatures of injections and of hot well, will be taken with standard thermometers in the case of condensing engines.

ARTICLE 15. Water.

The water used will be taken from the city mains.

The feed water for the boilers will be weighed by means of scales, and a large tank, and will be run into a smaller supplemental tank, from which it will be pumped into the test boilers by means of a feed-pump, actuated by steam from other boilers.

The condensing water used will, in the case of condensing engines, be measured after leaving the hot well, in two carefully gauged tanks, alternately filled and emptied, the temperature also being taken.

The known weight of steam used will be subtracted from the overflow.

The injection water will be weighed in large tanks, and its temperature taken.

The injection water will not be delivered under pressure.

ARTICLE 16. Speed of Engine.

The number of revolutions of the engine will be taken by a continuous counter attached to the crank shaft.

The variations in speed for one minute will be taken at each quarter of an hour by means of an electric chronograph, connected with a standard clock beating seconds.

The variations in speed during one stroke will be taken by an acoustic chronograph at fifteen minutes interval.

Special tests of speed alone, under varying loads, will be made if desired, and close attention will be had to this point in all cases.

ARTICLE 17. Barometric Measurements.

A standard barometer and thermometer will be read at fifteen minutes interval during the trial.

ARTICLE 18. Vacuum.

The vacuum of condensing engines will be read by a gauge, carefully compared before and after the trials.

ARTICLE 19. Testing of Gauges, Indicators, etc.

All of the gauges, indicators and thermometers used, shall be carefully tested before and after the trials, and the party whose engine is tested, shall have the right to be present in person or by agent, at these tests.

ARTICLE 20. Diagrams.

The indicator diagrams will be taken at fifteen (15) minutes intervals, and will be read for:

Initial pressure,	Mean effective pressure,
Pressure at cut-off,	Point of cut-off,
Terminal pressure,	Release of steam,
Counter pressure at mid-stroke,	Exhaust closure.
Maximum compression pressure,	

From the diagrams will be computed the indicated steam at the point of cut-off, and at release, as also the actual steam from boilers per horse-power per hour.

Article 21. Load of the Engine.

The Committee of Judges will test the engine at the load desired by the exhibitor of it, unless circumstances shall render it impossible to meet his wishes.

If the load does not exceed seventy-five (75) indicated horse-power, the net load will be measured by a Transmitting Dynamometer.

Article 22. Friction Diagrams.

At the close of the regular trial, the engine will have its belt taken off, and be run for one hour for friction diagrams.

Article 23. Duration of the Trials.

Unless otherwise arranged, the trials will last ten (10) hours.

Article 24. Economy and Efficiency of the Engine.

No account will be taken of the coal burned, but the economy of the engine will be deduced from the actual steam used and water weighed to the boiler.

The trial will begin with the established pressure.

The level of the water in the boiler, and the pressure of the steam will be kept as nearly constant, as possible, during the whole of the trial.

The whole weight of the water fed to the boiler, subject to proper deductions for waste, and to corrections for variation of level in the boiler, will be multiplied by its thermal value as steam at the steam-chest, and divided by the product of the indicated horse-power of the engine, and the number of hours of the test.

The resulting quotient will be used to divide twenty-five hundred and fifty-seven and sixty-nine one-hundreths (2557·69) British thermal units, giving the efficiency of the engine as compared with the mechanical equivalent of the heat furnished to it, and therefore its efficiency, as a means of converting heat into work.

The net horse-power of the engine will be used for computation similarly to the indicated horse-power, and the result will be taken as the measure of the efficiency of the engine, both as a means of converting heat into work, and as a machine for the transmission of power.

This latter shall be considered the true measure of the efficiency of the engine.

METHODS USED.

TIME OF TEST.

It was the intention that each of these tests should last exactly ten (10) hours. But in the case of the Porter-Allen engine, the engine was stopped to change indicator, and in the case of the Southwark engine, the test lasted eleven (11) hours and two (2) minutes.

STEAM.

The steam used in the engine tests was taken from a boiler which was not in use for any other purpose, and had all valves connecting with other boilers and engines tightly closed. It was not practicable that the steam pipe should be run directly from the boiler used to the engine tested, and in the cases of the Southwark and Porter-Allen engines the steam pipe was very long, and had a number of pockets, in which steam and condensed water lodged. The engines were in all cases run for a considerable time before the tests began, and an endeavor was made to leave the boiler, engine and all their attachments at the end of the test in the same condition as at the beginning.

Before beginning the tests, the level of the water in the boiler was noted, and all water supplied to the boiler after the test began was carefully weighed, so that the amount of water supplied to the engine is known. All water used in calorimetric tests was credited to the engine, and all drips from the main steam pipe were returned to the tanks and used again. The level of the water at the end of the test was brought back to the same point as at the beginning.

DISPLACEMENT AND CLEARANCE.

Before beginning the tests, the engine was put on each dead centre, and the volume on each side of the piston was filled with water, the valve being moved so that it covered the port in each case. The weight of the water required to fill the space and its temperature were taken at the same time, and from this data the displacement of the piston and clearance on each end was calculated.

REVOLUTIONS.

A Crosby revolution counter was attached to the shaft of each engine, and the reading of the counter was taken at regular intervals. After the counter had been adjusted for the engine, it worked

satisfactorily on the Porter-Allen and Buckeye tests, and during the Southwark test, until 4.15 P. M. The number of revolutions on this test after this time are computed from the number of revolutions made by the dynamometer.

BAROMETER.

The readings of the barometer were taken from observations of the U. S. Signal Service in Philadelphia.

PRESSURE AND TEMPERATURE OF THE STEAM.

The pressure of the steam at the engine and at the boiler was taken at regular intervals, and the temperature of the steam was taken at the engine by means of a high grade thermometer set into the branch steam pipe, which led to the calorimeter used, and was very close to the engine.

QUALITY OF THE STEAM.

This was determined by using the Barrus calorimeter, a description of which is given in the Report of the Committee on Steam Boilers.

INDICATOR CARDS.

The indicated horse-power of the engines was taken. The indicator motions used were practically exact. A Crosby and a Tabor indicator were used on each cylinder, and a Crosby was used on the valve chest.

On the Porter-Allen engine test, the indicators were changed when the test was half concluded, and as the cards taken by the two indicators from the same end were as nearly identical as possible, the indicators were not changed during the other tests.

The indicator springs were tested against a Crosby steam gauge, and were found to be practically correct both in ascending and descending.

HORSE-POWER.

The areas of the cards were taken by a Crosby planimeter. The length of the cards were measured to $\frac{1}{100}$ of an inch. The mean effective pressure was determined from this data. The constant for each end of the cylinder was found by dividing the displacement in cubic inches (found by experiment) by twelve times 33,000. This result, multiplied by the mean effective pressure

and by the number of revolutions, gives the horse-power developed in one end of the cylinder. The sum of these results is the total indicated horse-power of the engine.

MEAN INDICATOR CARD.

On each indicator card lines were drawn at right angles to the atmospheric line at the ends of the card, and also at ·05, ·1, ·2—·8, ·9, ·95, the length of the card. The distance from the atmospheric line to both the top and bottom of the card was measured in $\frac{1}{100}$ of an inch and tabulated, by Mr. Green, of the University of Pennsylvania.

A mean of these tabulated results is taken as the mean indicator card from which the amount of water accounted for by the indicator card is calculated. A mean of all the steam chest cards has been taken in the same way, and the mean card has been drawn. It is to be remembered that these mean cards are exactly right only at the points of the stroke already mentioned, and that this card is made of the general shape of cards actually taken.

WATER ACCOUNTED FOR BY INDICATOR CARDS.

In determining the amount of water accounted for on the indicator card, the volume of the cylinder to ·3, ·4, etc., of the stroke, including clearance, has been multiplied by the weight of one cubic foot of steam at the pressure corresponding to that point of the stroke, and from this has been subtracted the volume of the clearance multiplied by the weight of one cubic foot of steam, at the pressure to which the steam has been raised by compression.

This amount being calculated separately for each end of the cylinder, gives the weight of steam accounted for on the card for each stroke. Adding these results together and multiplying by sixty times the mean number of revolutions per minute, gives the total weight of steam accounted for per hour, and dividing by the mean horse-power, gives the water used per horse-power per hour. *It must be remembered that this is on the supposition that the steam in the cylinder was dry and saturated.*

REGULARITY OF SPEED.

These results are given at the end of this report.

The chronograph used consisted of a cylinder about four (4) inches in diameter, revolved by means of clock-work. In front of

this cylinder, carried on a movable table, were two magnets with the armatures arranged in such a way that, when the circuit was closed, a point on the armature rested against the drum, and when the circuit was broken, the point was drawn back from the drum. One of these magnets was actuated by a tuning fork, making about ninety-eight double vibrations per minute, the tuning fork being kept constantly in vibration by a magnet, whose circuit is made and broken by the fork itself.

The other magnet can be actuated in any way, and the records of the two points are side by side on the drum.

During the tests, the circuit of the second magnet was made and broken at each revolution of the engine. The cylinder was covered with smoked paper, and the records made were preserved by dipping them in shellac.

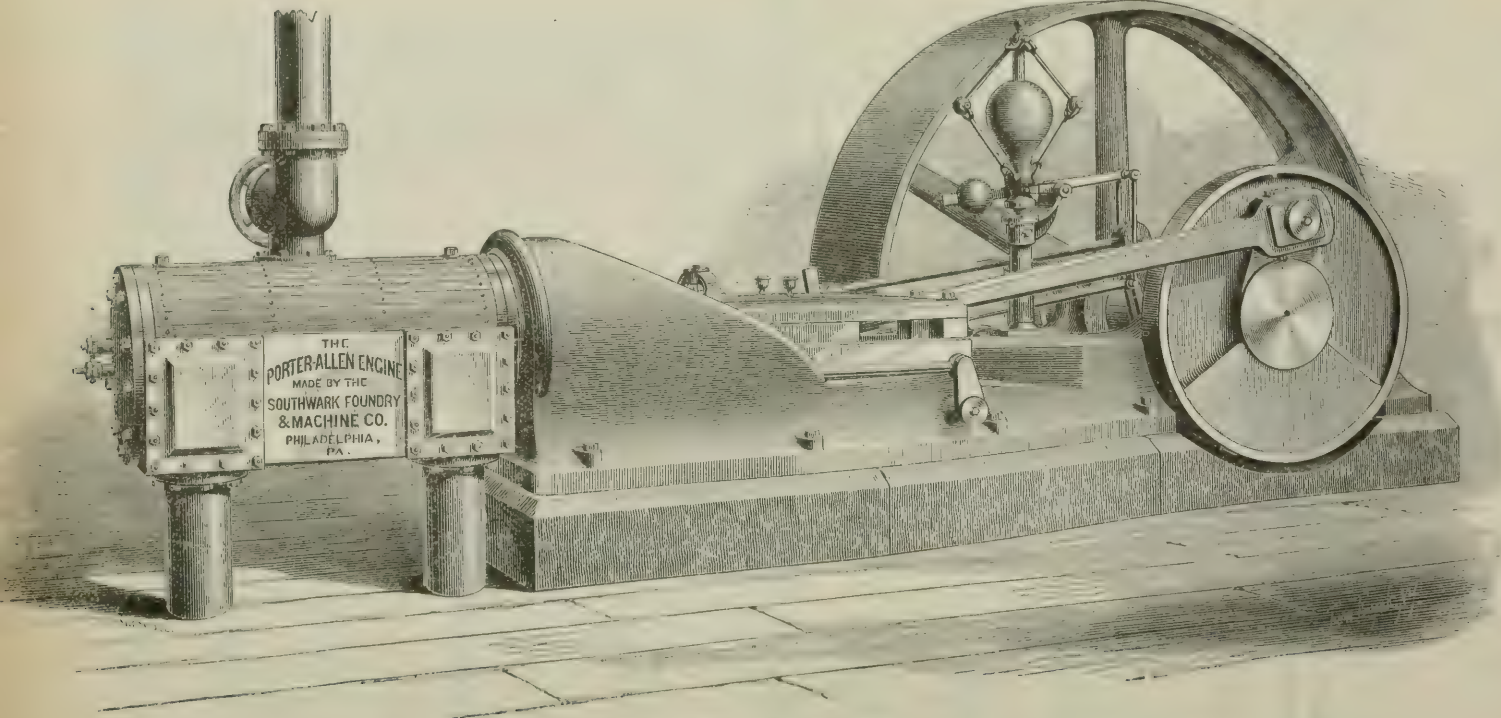
The record then shows the number of vibrations of the tuning fork occurring during successive revolutions of the engine. As it takes considerable time to prepare and adjust the apparatus, it was not possible to make continuous records.

PORTER-ALLEN ENGINE.

Test began,	1·10 P. M., October 23, 1884.
" ended,	11·10 P. M., October 23, 1884.

The engines was stopped 2·9 minutes at 6·15 P. M. to change indicators.

Diameter cylinder,	11½ inches.
Stroke,	20 "
Diameter piston rod,	1¾ "
" steam pipe,	5 "
" exhaust pipe,	5 "
Area steam ports,	6·75 square inches.
" exhaust "	10·94 " "
Diameter fly wheel (belt drum),	66 inches.
Face of " "	15 "
Weight of " "	1,000 pounds.
" " engine complete,	8,500 "
Displacement (measured)—	
Crank end of cylinder,	2018·3 cubic inches.
Head " " "	2070·14 " "
Clearance (measured)—	
Crank end,	127·87 cubic inches.
" "	6·33 % displacem't.
Head end,	136·94 cubic inches.
" "	6·61 % displacem't.
Water used in engine,	27849·07 pounds.



The Porter-Allen Engine.

Total time engine in operation, ...	9 hours 57·1 min.
Mean revolutions per minute, ...	227·51
Maximum " "	230·2
Minimum " "	221·8
Variation from mean speed, ...	+1·18 per cent.
" " " "	—2·51 " "
Mean horse-power (indicated) of engines, . .	69·34
Maximum " " " . .	76·16
Minimum " " " . .	63·16
Mean temperature of steam at engine, . . .	329·33°
Maximum " " " . . .	338·°
Minimum " " " . . .	306·5°
Mean pressure " " . . .	90·5 pounds.
Maximum " " " . . .	101·6 "
Minimum " " " . . .	59·0 "
Mean " " at boiler, . . .	92·8 "
Maximum " " " . . .	104·3 "
Minimum " " " . . .	61·0 "
Mean barometer, ...	30·059 inches.
Mean temperature of air, ...	47·4° Fahr.
Mean power required to run engine with load off,	5·16 H. P.

QUALITY OF THE STEAM.

An attachment was made to the steam pipe just above the valve chest for the Barrus calorimeter, and the following results were obtained from its use:

From 4·40 to 6·40 P. M., October 23d, steam contains 13·36 % moisture
" 6·40 " 8·40 " " " " " 3·23 % "
" 8·40 " 11·10 " " " " " 6·44 % "

The average quality of the steam from this, is that it contained 7·56 per cent. of moisture.

The results of this test are shown graphically in *Fig. 1*.

The scales to which the different parts of the diagram are drawn, are shown on the left hand side of the figure. The base is divided into ten (10) minutes intervals, and the ordinates are laid off correspondingly to the observations made at the regular intervals during the test.

The line marked "Total horse-power" shows the variation in the indicated horse-power during the test.

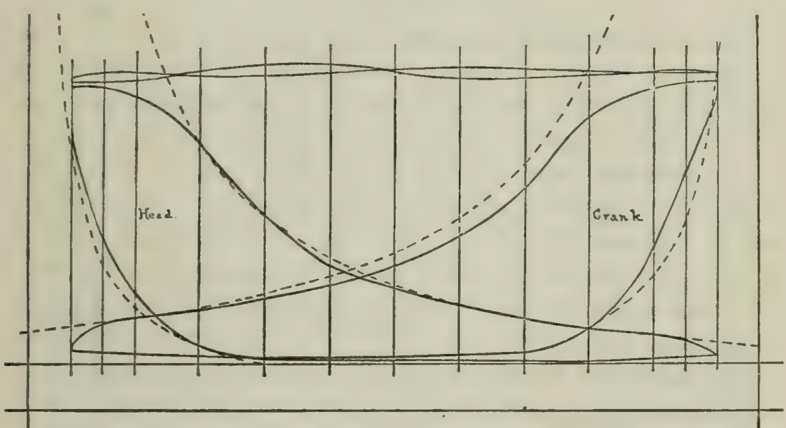
The line marked "Pressure at boiler," shows the variation in steam pressure at the boiler, while the line just below it marked "Pressure at engine," shows the corresponding pressure at the engine.

The line marked "Horse-power follower end" shows the indicated horse-power developed in the end of the cylinder away from the crank, while the line "Horse-power crank end" shows the corresponding power developed in the end of the cylinder nearest the crank.

The sun of the ordinates of the last named lines, should equal the ordinate of the line marked "Total horse-power."

The line marked "Revolutions" shows the variation of the speed of the engine, each ordinate representing the mean number of revolutions for the preceding ten (10) minutes. It will be noticed that the base line does not represent 0 revolutions, but 200. This was done that the variations should be represented on a large scale, and to make the figure as small as possible.

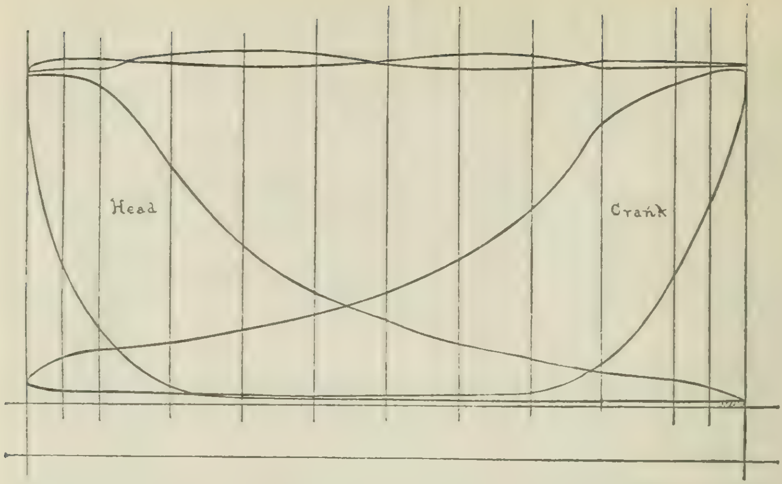
In the diagram, a break is to be noticed in the different lines at 6·15. It would have been more exact to have drawn the lines to the base line instead of breaking them.



Mean Card.—(Porter-Allen Engine.)

FIG. 2.

Fig. 2 shows the mean of all the indicator cards taken during the test, the mean being determined as before described. The clearance line is drawn at each end of the diagram, and the theoretical (hyperbola) expansion and compression lines have been drawn. The scale to which the diagrams are drawn is twenty five pounds to one inch, and the diagrams in the original are made uniformly, eight (8) inches long.



Porter-Allen, 69·38 Horse-power, 8·45 P. M., Oct. 23, 1884.

FIG. 3.

Fig. 3 is a reproduction of the cards taken at 8·45 P. M., October 23d, showing 69·38 horse-power. This card was chosen, because it comes more nearly to the mean horse-power than any other that was taken.

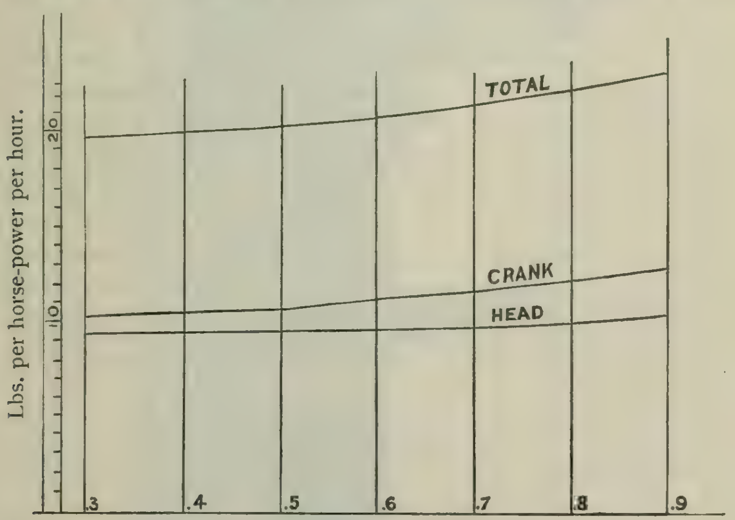
The pressures corresponding to the different parts of the stroke on the mean indicator card, are given in Table I. The first column *A* shows the points of the stroke. The columns headed *B*, show the pressure in the end of the cylinder away from the shaft, while making the stroke towards the shaft and returning, and the column headed *C*, shows the pressures in the opposite end. The column headed *D*, shows the quantity of dry saturated steam used in the cylinder per horse-power per hour from the indicator cards, using the mean number of revolutions and the mean horse-power, and allowing for the amount of steam compressed in the clearance. Re-evaporation after initial condensation is clearly shown by this:

TABLE I.

A. Part of Stroke.	*B.* Head End Cylinder.		*C.* Crank End Cylinder.		*D.* Steam Accounted for in both Ends of Cylinder.
	Advancing.	Returning.	Advancing.	Returning.	
Beginning.	86·28	70·00	87·82	81·63	Clearance, 6·3107 pds.
·05	86·22	38·00	87·72	59·86	
·1	83·88	20·79	85·30	36·42	
·2	69·62	5·47	77·10	11·12	
·3	46·60	2·00	54·72	3·18	19·8733
·4	32·80	1·64	39·70	2·58	20·0799
·5	24·04	1·40	30·42	2·38	20·3880
·6	18·11	1·22	24·40	2·40	20·8786
·7	14·03	1·05	20·18	2·42	21·5601
·8	10·92	9·6	17·06	2·63	22·2940
·9	8·92	1·21	14·84	3·18	23·3827
·95	6·82	1·60	12·74	3·36	
End.	1·88	1·85	6·82	4·32	

The amount of water used by actual weight is 44·307 pounds per horse-power per hour.

No explanation is offered save that already given as to the cause of this discrepancy between the amount of water actually

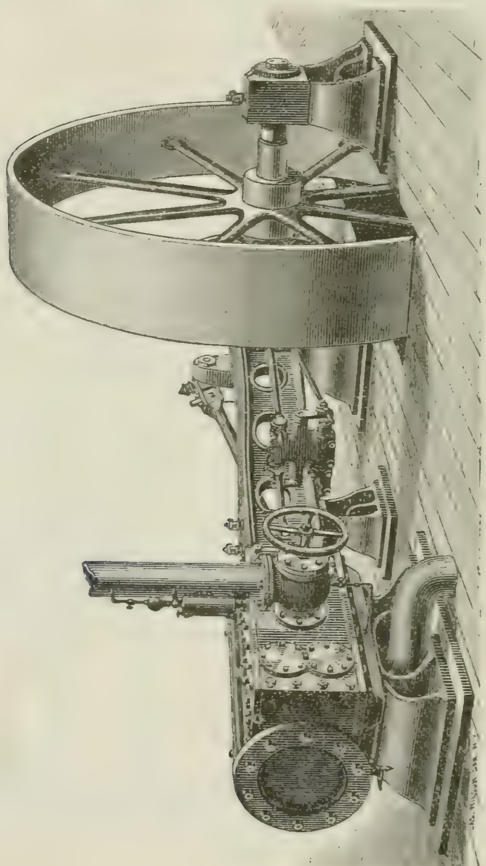


Water in Cylinder. (Porter-Allen.)

FIG. 4.

used in the cylinder and that shown on the indicator cards. The calorimeter test, which cannot be relied upon as accurate, showed an average of 7·56 per cent. of moisture in the steam. At ·9 the stroke where the amount of water shown by the cards is the greatest, the weight of water would be only $\frac{23 \cdot 3827}{\cdot 9244} = 25 \cdot 295$ pounds, whereas 44·307 pounds actually passed through the cylinder.

Fig. 4 shows the amount of dry saturated steam which should have been present in the cylinder at the different points of each stroke, together with their sum, the upper line being simply a graphic representation of column *D*, of Table I.



The Buckeye Engine.

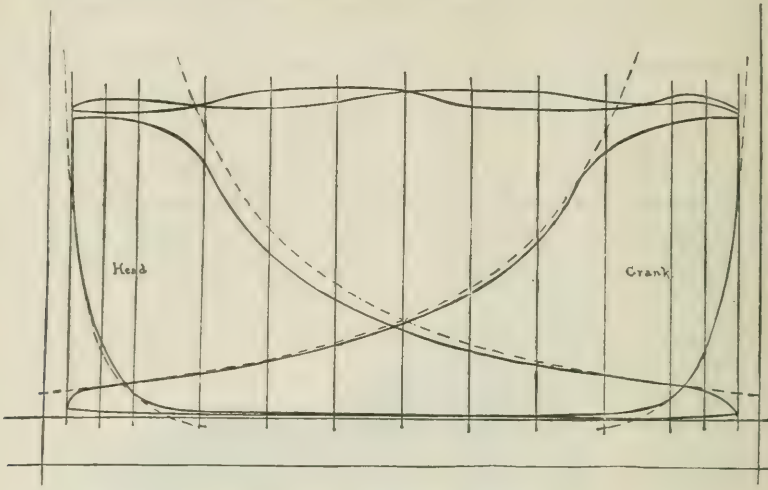
BUCKEYE ENGINE.

Test began,	6 P. M., October 31, 1884.
" ended,	4 A. M., November 1, 1884.
Diameter cylinder,	10 inches.
Stroke,	20 "
Diameter piston rod,	1½ "
" steam pipe,	3½ "
" exhaust "	4 "
Area steam ports,	⅝ x 8¾ inches.
" exhaust "	⅞ x 8¾ "
Diameter fly wheel,	84 inches.
Face of " "	19 "
Weight of fly wheel,	3200 pounds.
Weight of engine complete,	9800 "
Displacement (measured)—	
Crank end,	1464·48 cubic inches.
Head end,	1557·36 " "
Clearance (measured) to face of cut-off—	
Crank end,	47·95 " "
" "	3·27 % displacem't.
Head end,	53·57 inches.
" "	3·44 % displacem't.
Water used in engine,	16803·30 pounds.
Total time engine in operation,	10 hours.
Mean revolutions per minute,	201·11
Maximum " " "	205·6
Minimum, " " "	194·4
Variation from mean speed,	+ 2·23 per cent.
" " " "	— 3·33 " "
Mean indicated horse-power,	54·32
Maximum, " " "	56·27
Minimum, " " "	52·35
Mean temperature of steam at engine,	332·83°
Maximum, " " "	390·°
Minimum, " " "	304·5°
Mean pressure of steam at engine,	98·04 pounds.
Maximum " " "	107·30 "
Minimum " " "	89·80 "
Mean barometer,	30·012
Mean temperature of air,	46°
Mean power required to run the engine with the load off,	5·26 H. P.

QUALITY OF THE STEAM.

The quality of the steam from one observation, lasting from 7·35 to 9·00 P. M., showed the steam to contain 7·6 per cent. of moisture.

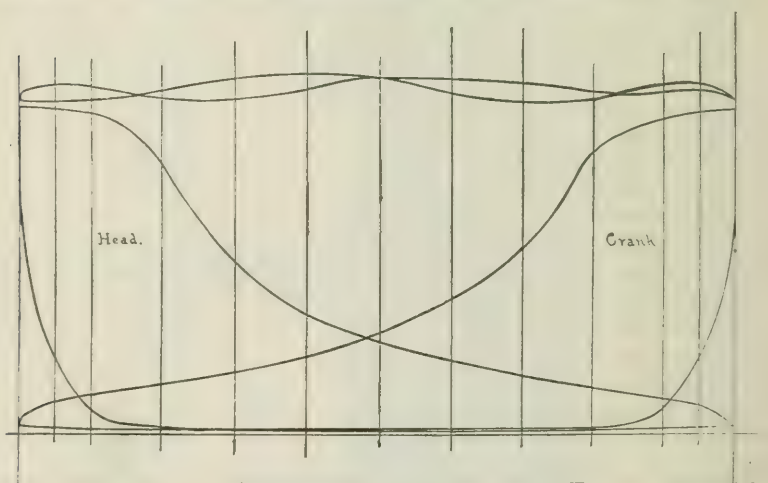
The results of this test are shown graphically in *Fig. 5*. The lines are drawn in the same way as already described for *Fig. 1*, the only difference being a slight change of scale.



Mean Card. (Buckeye Engine.)

FIG. 6.

Fig. 6 shows the mean of all the indicator cards taken during the test, the mean being determined as before described.



Buckeye, 54·34 Horse-power, 11.20 P. M., Oct. 31, 1884.

FIG. 7.

Fig. 7 is a reproduction of the cards taken at 11·20 P. M., October 31, 1884, showing 54·34 horse-power. This card was chosen because it comes more nearly to the mean horse-power than any other that was taken.

The pressures corresponding to the different parts of the stroke, which would give the mean indicator card, are given in Table II.

The first column *A* shows the points of the stroke, *B* is the pressure in the end of the cylinder away from the shaft, while the piston is making the stroke towards the shaft and returning. *C* is the pressure in the opposite end. *D* is the quantity of dry saturated steam in the cylinder per horse-power per hour from the indicator card, using the mean number of revolutions and the mean horse-power, and allowing for the amount of steam compressed in the clearance.

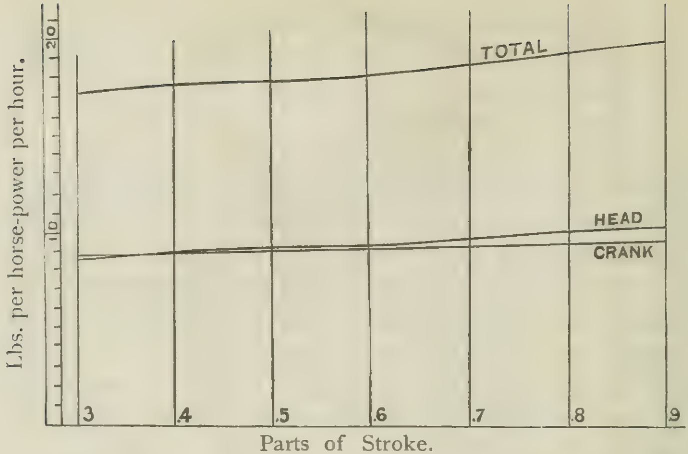
TABLE II.

A. Part of Stroke.	*B.* Head End Cylinder.		*C.* Crank End Cylinder.		*D.* Steam Accounted for in Both Ends of Cylinder.
	Advancing.	Returning.	Advancing.	Returning.	
Beginning	90·58	78·72	90·95	76·52	
·05	90·49	21·82	90·95	20·34	
·1	89·46	6·94	89·86	6·40	
·2	76·76	1·79	80·42	1·39	
·3	49·25	1·62	52·94	1·14	17·310
·4	35·04	1·50	37·40	1·08	17·743
·5	26·32	1·38	28·18	·94	18·270
·6	20·40	1·00	21·64	·90	18·713
·7	16·29	·56	16·98	·92	19·226
·8	13·12	·42	13·40	1·04	19·689
·9	10·39	·52	10·65	1·22	20·062
·95	8·28	·68	9·26	1·49	
End.	1·95	1·95	3·76	2·40	

Amount of water used by actual weight $= \dfrac{16803 \cdot 3}{10 \times 54 \cdot 32} = 30 \cdot 93$ pounds.

This engine was immediately adjacent to the boiler.

As the calorimeter test shows but 7·6 per cent. of moisture, it is evident that the steam shown on the card and that actually passing through the cylinder, vary greatly.



Steam in Cylinder. (Buckeye Engine.)

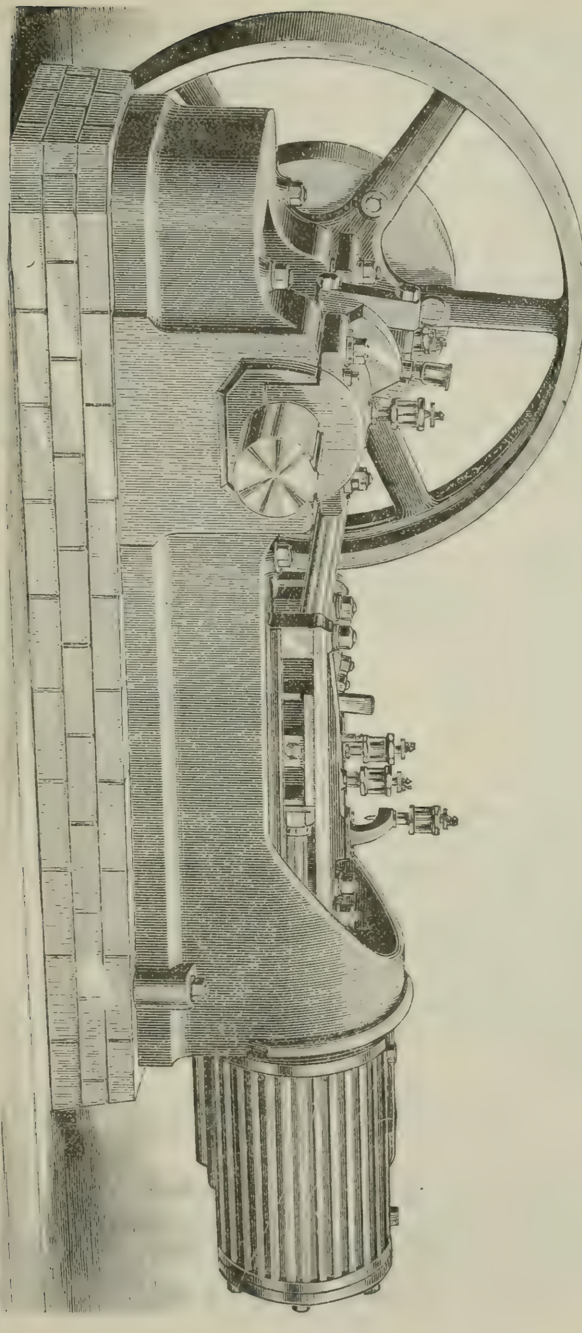
FIG. 8.

Fig. 8 shows the relative weights of dry saturated steam that should be present (theoretically) in the cylinder at different points of the stroke, together with the amount per horse-power per hour, as shown in Table II.

The power given off by this engine was transmitted directly to a Van Depoele dynamo mounted on a Brackett dynamometer cradle, and readings were taken from this dynamometer while the indicator cards were being taken. As the dynamometer was afterwards shown to be inaccurate, the results are here omitted. It is to be regretted that circumstances did not allow of a special test to determine the net horse-power delivered.

SOUTHWARK ENGINE.

Test began,	1 P. M., November 8, 1884.
" ended,	12·02 A. M., " 9, 1884.
Diameter cylinder,	9 inches.
Stroke,	10 "
Diameter piston rod,	1½ "
" steam pipe,	3 "
" exhaust "	3½ "
Area steam port,	5·7 square inches.
" exhaust "	5·7 " "
Diameter fly wheel (belt drum),	40 inches.
Face of "	8½ "
Weight of "	400 pounds.



The Southwark Engine.

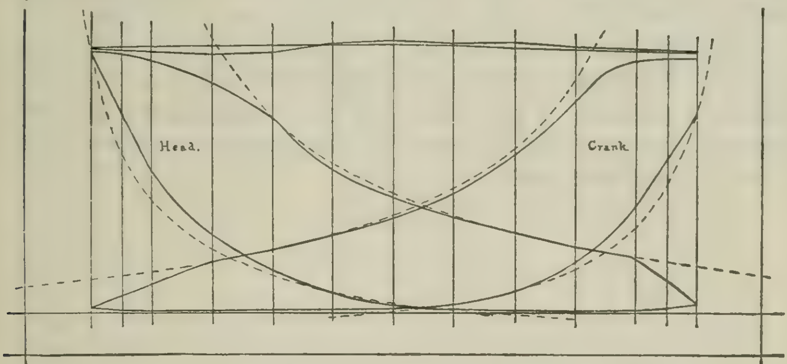
Weight of engine, complete,	2,600 pounds.
Displacement (measured)—	
Crank end,	606·03 cubic inches.
Head end,	633·31 " "
Clearance, (measured)—	
Crank end,	66·1 " "
" "	10·91 % displacem't.
Head end,	70·42 cubic inches.
" "	11·12 % displacem't.
Water used in engine,	14792·07 pounds.
Total time engine in operation,	11 hours, 2 minutes.
Mean revolutions per minute,	305·06
Maximum " "	309·87
Minimum " "	301·
Variation from mean speed,	+1·57 per cent.
" " " "	−1·33 " "
Mean horse-power of engine,	29·11
Maximum " " "	46·82
Minimum " " "	14·97
Mean temperature of steam at engine,	329·16°
Maximum " " "	335·°
Minimum " " "	315·°
Mean pressure " "	87·58 pounds.
Maximum " " "	96·0 "
Minimum " " "	68·5 "
Mean " " at boiler,	92·97 "
Maximum " " "	101·3 "
Minimum " " "	73·0 "
Mean barometer,	30·256
Mean thermometer,	
Mean horse-power delivered, as shown by Tatham's dynamometer,	23·44
Maximum horse-power delivered, as shown by Tatham's dynamometer,	43·15
Minimum horse-power delivered, as shown by Tatham's dynamometer,	9·13
Mean horse-power required to run engine with belt off,	4·68

QUALITY OF THE STEAM.

From 3·10 to 4·10 P. M., November 8th, steam contained,	6·7 % moisture.
From 9·50 to 10·55 P. M., November 8th, steam contained,	9·15 % "
Mean quality of steam, containing,	7·92 % "

The results of this test are shown graphically in *Fig. 9.* In

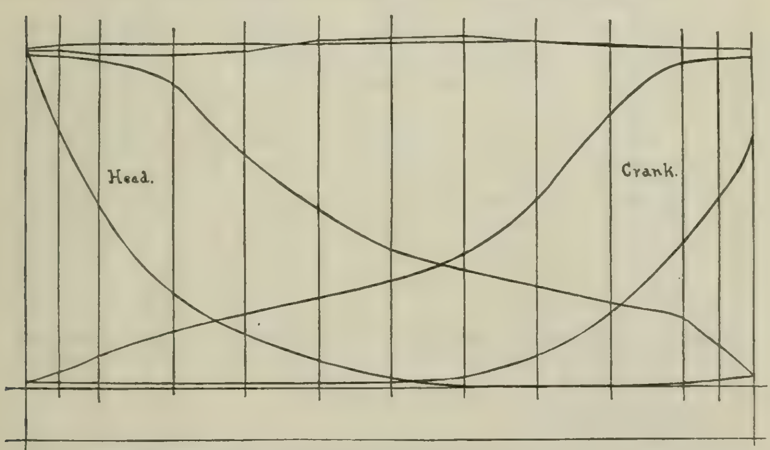
addition to the lines which have already been described, there is one marked "Horse-power from dynamometer," which represents the horse-power delivered by the engine to the Tatham Dynamometer.



Mean Card. (Southwark Engine.)

FIG. 10.

Fig. 10 shows the mean of all the indicator cards taken during the test, the mean being determined as before described.



Southwark, 29·21 Horse-power, Nov. 8, 7·15 P. M., 1884.

FIG. 11.

Fig. 11 is a reproduction of the cards taken at 7·15 P. M., November 8, 1884, showing 29·21 horse-power. This card was chosen, because it comes more nearly to the mean horse-power than any other that was taken during the test.

The pressures corresponding to the different parts of the stroke, which would give the mean indicator card, are given in Table III.

The first column *A* shows the points of the stroke. *B* is the pressure in the end of the cylinder away from the shaft, while the piston is making the stroke towards the shaft and returning. *C* is the pressure in the opposite end. *D* is the quantity of dry saturated steam in the cylinder per horse-power per hour from the indicator card, using the mean number of revolutions and the mean horse-power, and allowing for the amount of steam compressed in the clearance.

TABLE III.

A. Part of Stroke.	*B.* Head End Cylinder.		*C.* Crank End Cylinder.		*D.* Steam Accounted for in both Ends of Cylinder.
	Advancing.	Returning.	Advancing.	Returning.	
Beginning.	86·80	87·56	84·99	67·14	
·05	86·08	66·21	84·99	50·55	
·1	83·90	47·38	84·32	35·02	
·2	76·69	25·56	71·05	16·92	
·3	62·58	14·25	52·62	7·00	20·781
·4	47·51	6·36	39·40	2·44	21·201
·5	37·97	2·17	31·84	1·36	22·155
·6	32·06	0·44	25·60	1·08	23·107
·7	26·75	0·07	20·90	·69	23·076
·8	22·38	0·11	17·08	·42	24·045
·9	18·24	0·49	9·74	·58	
·95	11·20	1·46	5·27	1·16	
End.	3·47	2·77	1·98	1·80	

The amount of water used by actual weight per horse-power per hour $= \dfrac{14792{\cdot}07}{11\frac{1}{30} \times 29{\cdot}11} = 46{\cdot}05$ pounds.

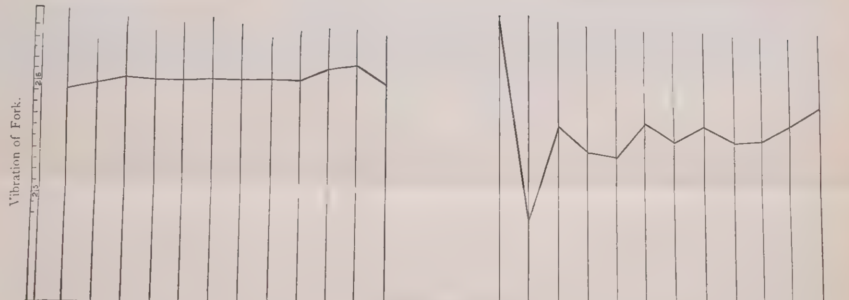
The load on this engine consisted of the Tatham dynamometer and a friction brake, and the variation in this latter caused the great variation in the horse-power lines on *Fig. 9*.

Fig. 12 shows the relative weights of dry saturated steam that should be present (theoretically) in the cylinder at different points of the stroke, together with the amount for horse-power per hour, as shown in Table III.

rom
ions
may
ıter-

suc-
the
ɜter-
sults
eing
the
that
ight

um-
ving
The
evo-
l to

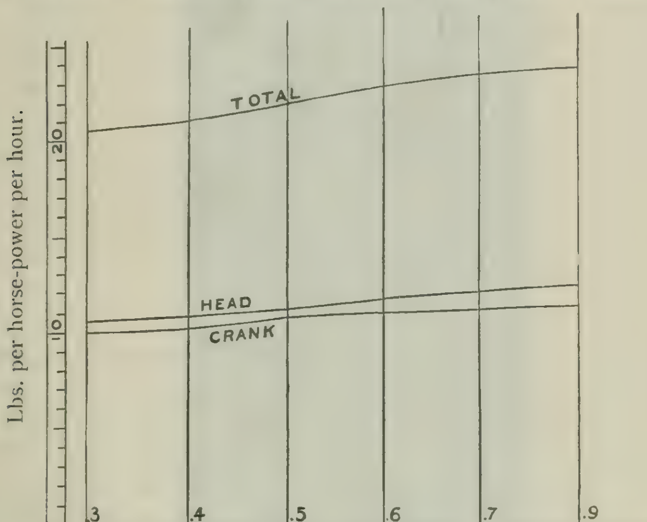


PORTER-ALLEN ENGINE

SOUTHWARK ENGINE

REGULARITY OF SPEED.

A good idea of the regularity of speed can be obtained from *Figs. 1, 5* and *6*, which show the average number of revolutions made by the engine for each ten or fifteen minutes, as the case may be. This only, however, gives the mean speed for successive inter-



Parts of Stroke.
Steam in Cylinder. (Southwark Engine.)
FIG. 12.

vals of time, and does not show the time required to make successive revolutions, which would be a more accurate test of the regularity. *Fig. 13* is a specimen of the record taken to determine the time of successive revolutions. *Fig. 14* shows the results of these experiments graphically, the horizontal distances being the successive revolutions, and the vertical distances being the time it takes to make each revolution, the unit of time being that of the double vibration of a tuning fork making about ninety-eight double vibrations per seconds.

During both the Porter-Allen and the Southwark tests a number of diagrams were taken, but only the results of those showing the last and greatest variation in speed are shown in *Fig. 14*. The following table, No. IV., gives the time of making successive revolutions in beats of the tuning fork, and they can be reduced to revolutions per minute by dividing with $5{,}880 = (98 \times 60)$:

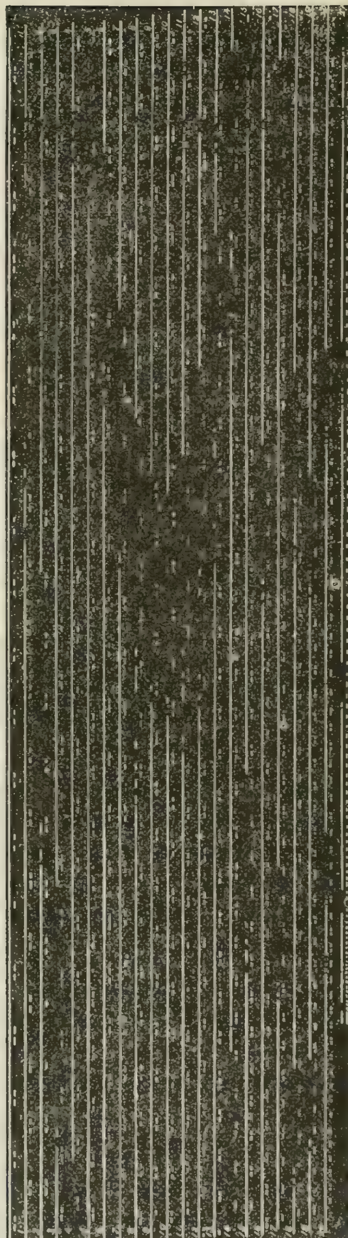


Fig. 13

TABLE IV.

Porter-Allen.		Southwark.	
Minimum Variation.	Maximum Variation.	Minimum Variation.	Maximum Variation.
25·92	26·51	18·75	19·3
25·96	24·72	19·00	19·1
26·13	25·56	19·0	19·2
26·00	25·33	19·0	19·2
26·00	25·30	19·0	18·8
26 07	25·60	19·0	18·7
26·00	25·43	18·9	18·7
26·01	25·55	18·9	18·8
26·00	25·41	19·0	19·0
26·10	25·43	18·9	19·0
26·13	25·57	19·0	19·0
25·95	25·71	19·0	19·0

The nearly continuous line of *Fig. 13* is from the armature, making record of the revolutions of the engine, and as the circuit was broken at only one point in the revolutions, the tracing point would make a continuous line, except during one small interval. The dots right under this line are made by the other armature. connected with the tuning fork. *Fig. 15* will show the manner of connecting and using the apparatus. All the apparatus shown in the figure, excepting the piece marked T and the cells V, W and X, is on one base and works as follows: The tuning fork Z is kept in vibration by means of the single Leclanché cell X, which is connected to the binding posts A and B. A is connected directly to the tuning fork E, as the whole apparatus rests on an iron base, and E and A are not insulated. The current passes from X to B, then around the magnet G, then to the insulated contact piece F, through the contact piece to the fork Z, from E to A, and back to the cell X.

The vibration of the fork makes and breaks contact at F, magnetizing and demagnetizing G and keeping the fork vibrating with about a constant amplitude of vibration.

The drum P is the drum on which the records are made. N and O are two small magnets with their armature balanced horizontally in such a way that while the circuit is closed through them, the points a, a, rest against the drum, and when the circuit

is open a light spring draws the points clear of the drum. The magnet *O* is the one represented as recording the vibrations of the fork. The binding posts *I* and *K* are connected to the coil of the magnet.

The current from the cell *W* passes from *W* to the uninsulated post *C*. From *C* through the frame to the fork *Z*, through the

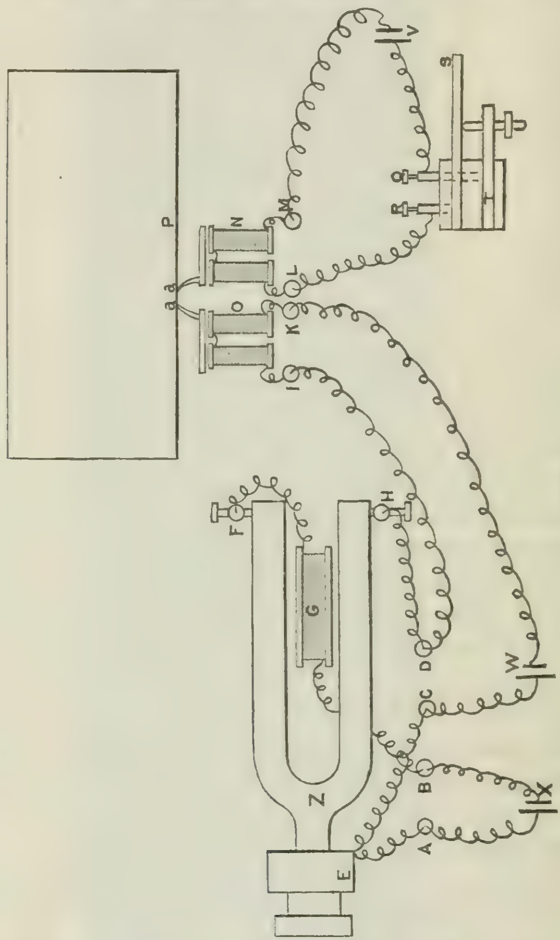


FIG. 15.

contact piece to the insulated post *H*, which is connected to the binding post *D*, also insulated. *D* is connected to *I* and the current, after passing through the coil of the magnet, passes through *K* back to the cell *W*. As the current is broken at *H* the point *a* is raised from the drum *P*, and as soon as the circuit is closed, the point *a* again rests on the drum *P*.

The record of the other magnet is made as follows: T is the break circuit piece. It consists of two brass pieces, S and T, insulated from each other and connected to the binding posts R and Q. U is a contact screw. S is put in such a position that a projection on the engine strikes S once a revolution, breaking contact with U. Connections are made, as shown, to the magnet N, and when the circuit is closed, the current flows through M, N, L, R, S, U, T, Q, and back to the cell V, in the order named.

In addition to the records made by this apparatus the following experiment was made on the Porter-Allen engine. The projecting end of the shaft was covered with blackened paper, and while the engine was in operation a point attached to one arm of a tuning fork was brought against the paper for a single revolution. This was repeated a number of times.

A straight line was drawn on the paper cutting the marks made by the fork, and the distance between successive vibrations has been plotted. The results are shown in *Fig. 16*. The ordinates are the actual distances between vibrations in inches. The abcissæ are equal intervals of time during one revolution. The points marked D represent the dead points. An examination will show that the changes in speed do not take place at any particular place in the stroke, and none of the diagrams taken show any more marked variation than those in the figure.

The thanks of this Committee are due to the following parties:

The Crosby Steam Gauge and Valve Company, Boston, Mass., for planimeters, gauges, indicators and test pumps, all of which proved of excellent workmanship.

The American Steam Gauge Company, Boston, Mass., for Tabor indicators, which worked well. A Mosscrop speed indicator, loaned by the same firm, was not used.

Riehlé Brothers, Philadelphia, Pa., for use of scales.

M. B. Edson, for a very accurate recording and alarm gauge.

The students of the Department of Dynamical Engineering, University of Pennsylvania, already mentioned in "Report on Boilers," for services as observers and computers.

As none of the exhibitors made application for a competitive test as prescribed under the code, all tests are quantitative. The uncertainty of the Committee as to the correctness of the calorimetric observations, and the fact that the engines were placed at

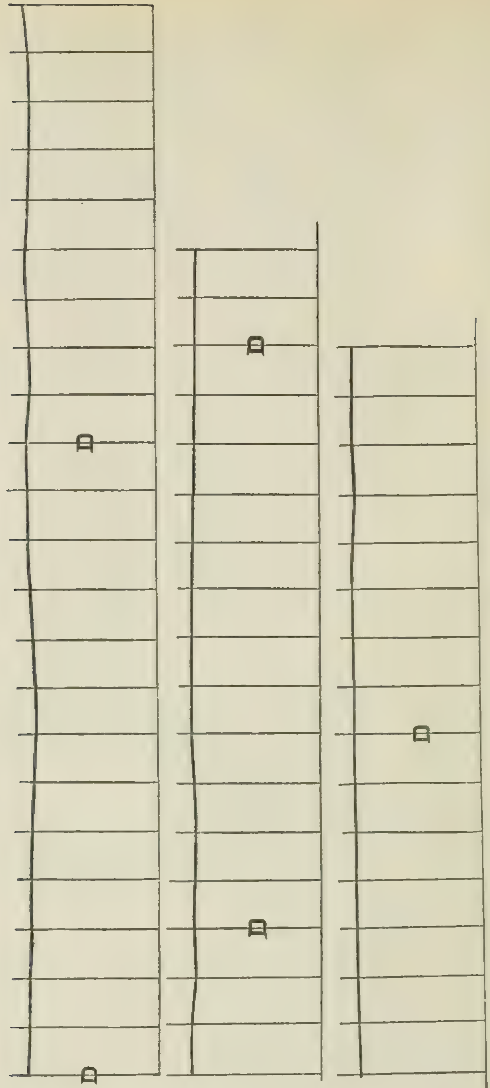
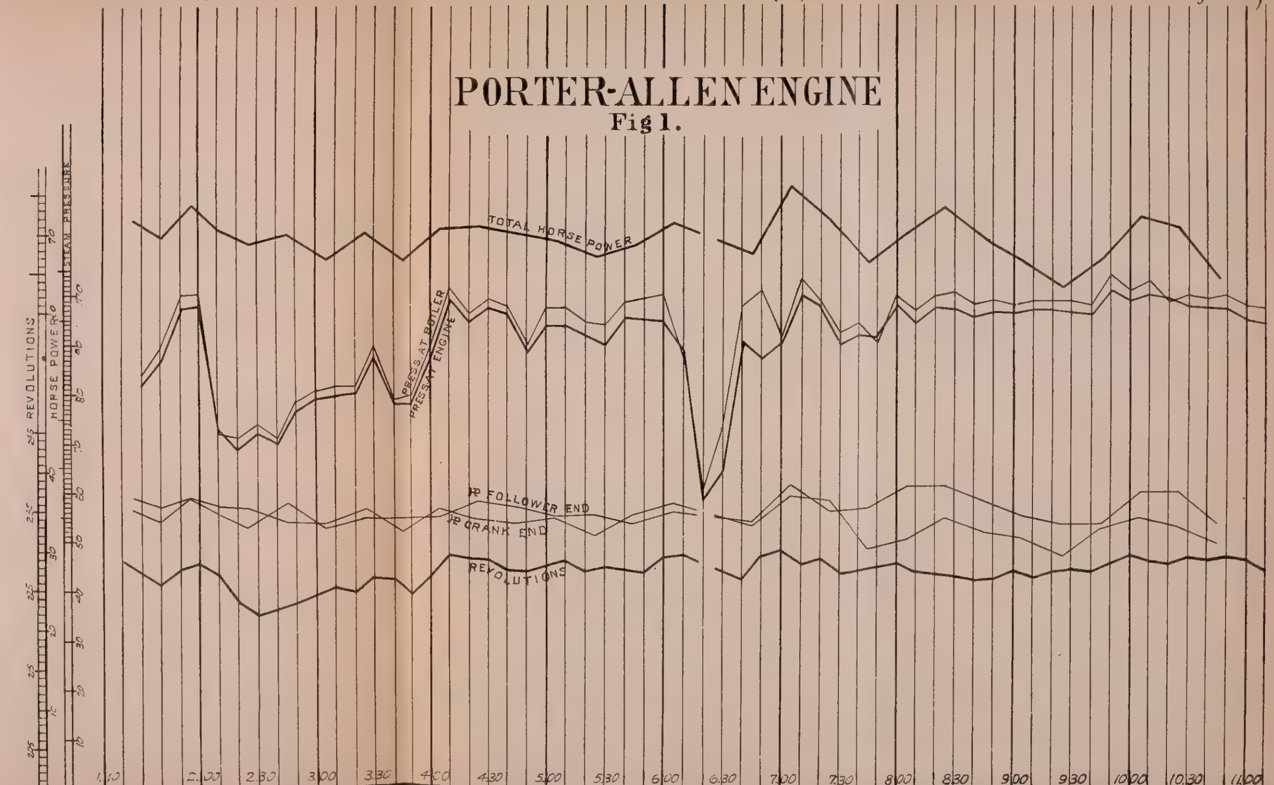


FIG. 16.

very different distances from the boiler feeding them, cause the Committee to submit their results without an expression of opinion.

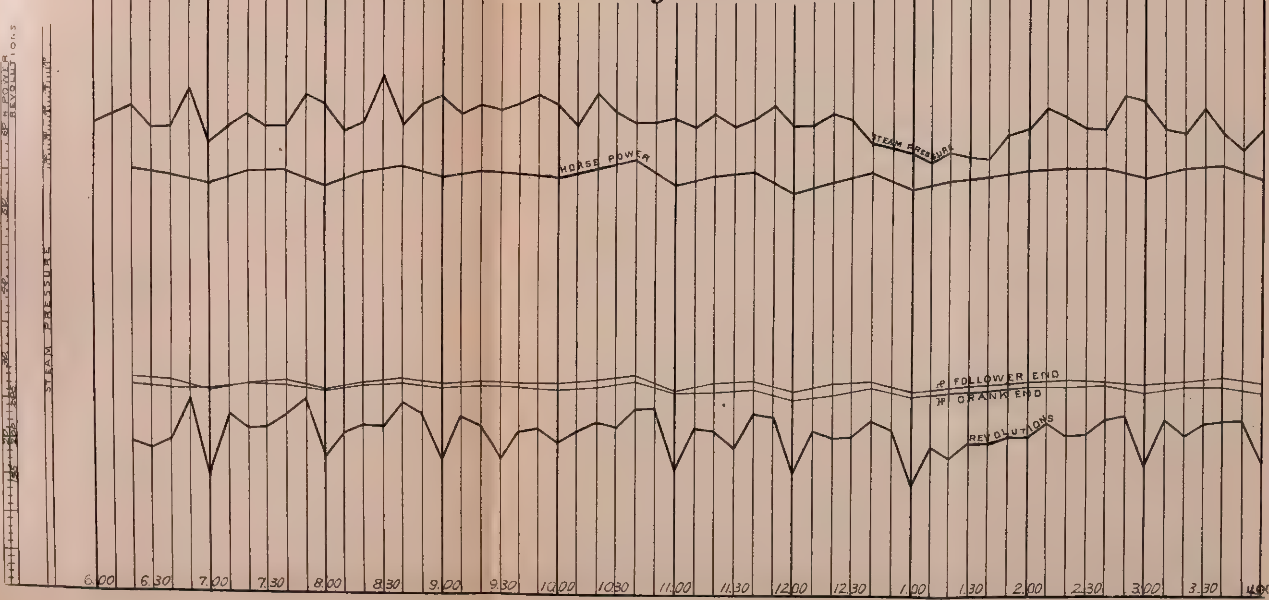
W. D. MARKS, *Chairman.*
CHAS. E. RONALDSON.
W. B. LEVAN.
Committee Present.
H. W. SPANGLER, *Secretary.*

PORTER-ALLEN ENGINE
Fig 1.



BUCKEYE ENGINE

Fig. 5.



SOUTHWARK ENGINE
Fig. 9.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XXII.

(*SECTION IV—A, CLASSES V, VI, VII OF THE CATALOGUE.*)

Supplementary Report on Meteorological and other Registers.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, MARCH, 1886.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1886.

EDITING COMMITTEE.

PERSIFOR FRAZER, *Chairman*,

CHARLES BULLOCK,

THEO. D. RAND,

COLEMAN SELLERS,

WILLIAM H. WAHL.

REPORT OF DR. LEONARD WALDO ON THE UNIFORMITY OF TEMPERATURE MAINTAINED IN THE INCUBATOR EXHIBITED BY THE PERFECT HATCHER COMPANY, OF ELMIRA, N. Y.

New Haven, September 1, 1885.

Professor M. W. Harrington, *Chairman of Sub-Committee, Section XXII, on "Self-Registering Instruments."*

Sir:—I submit herewith my report on the steadiness of temperature maintained in the incubator exhibited by the Perfect Hatcher Company, of Elmira, N. Y.

Respectfully yours,

Leonard Waldo.

REPORT.

For many purposes in physical science as well as in the arts, it is desirable to maintain approximate uniformity of temperature for considerable periods of time. It seemed probable from a superficial examination of the incubator exhibited by the Perfect Hatcher Company, of Elmira, N. Y., that a large measure of success had been attained by them. This instrument therefore received more careful consideration by your committee than would otherwise have been given to it. The following description and diagrams of the method of working is furnished by the makers:

In *Fig. 1*, there is a dead air space between top of tank E^2 and wood casing. The tank containing water is covered with a series of layers of paper, say twelve to twenty; then a solid building paper; then a frame work one inch thick to separate the walls of paper; then a layer of solid building paper next the wood cover. This forms a dead air space of one inch in thickness, besides the protecting walls. The object is to prevent the radiation of the heat from surface of tank upwards, and to cause it to deflect to egg chamber below; and it is claimed that this is effectually accomplished by this method. The cubic contents of air chambers are 6,468 inches. The outlet for the hot air was a valve 3 x 12 inches. The inlets for fresh air were four in number, and were 2 x 4½ inches. The openings in this test were 1 x 2½ inches, four in number. At every opening of the large valve, 3 x 12, on top of machine, the lamp flame was de-

creased to stop heating of water, and was restored to full flame when this valve was closed. The method of applying heat is by a kerosene oil lamp flame or gas flame. This flame heats water in the

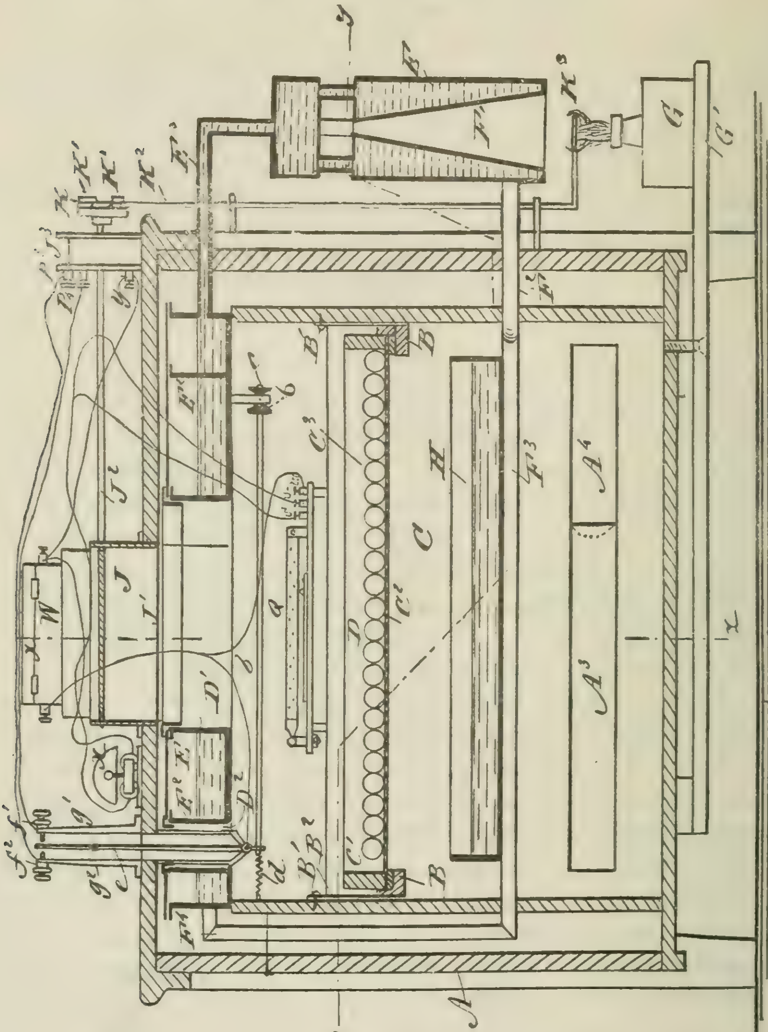


Fig. 1.

boiler, which circulates through tank and pipes in such a manner that the heat is evenly distributed throughout the chamber to be heated, etc.

PHILOSOPHY OF ITS OPERATION.

Fig. 1 shows a sectional view of the hatcher and all its working parts. On the right end is the boiler, F^1; under it the lamp G. Covering the entire top of the machine is the water tank, E^2; the water is heated in the boiler, E, passes through the tank in a series of channels, then out and down through pipes F^4 and F^3 back to boiler again to be re-heated. On top of these pipes are the open pans of water; the evaporation from these pans is in proportion to the heat furnished by the pipes—the hotter the pipes are, the more rapid the evaporation from the pans.

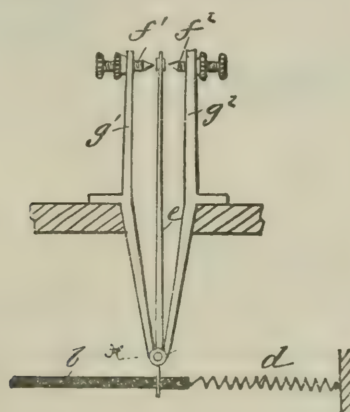


FIG. 2.

The heat is regulated automatically, as follows:

The rod b is hung rigidly at the right end, and firmly held in bracket by nuts c and 6; the end at left is attached to bottom of lever e; this lever is hung on the points of two screws, carefully adjusted so that the lever is perfectly free in its action. See also *Fig. 2*. This rod is exceedingly sensitive, to every variation of heat, expanding and contracting lengthwise with one-quarter of a degree variation. As it expands with the heat, it throws top of lever over towards regulating screw f^1 (see *Figs. 1* and *2*,) and as it contracts it throws the point of lever over against screw f^2. Whenever this lever comes in contact with either screw, it closes the electric circuit which causes the magnets L^3, *Fig. 3*, to pull down the armature L^2, which releases the fly pin M, *Fig 4*, and allows a quarter revolution of the clock, which opens or closes ventilators and turns up and down the lamp flame. When lever e comes in

contact with screw F^1, it causes ventilators to open and lamp flame to turn down, thus completely checking the heat, and when contact is made with screw F^2 the reverse takes place and heat is restored.

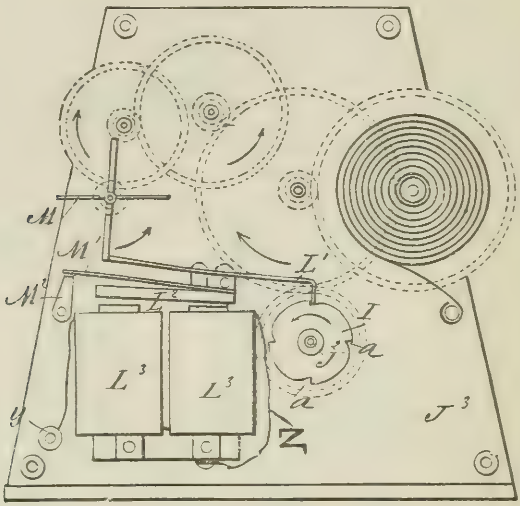


Fig. 3.

Your committee began the test for temperature steadiness on the morning of Thursday, October 2, 1884. There were present Messrs. M. W. Harrington, W. A. Rogers, and the writer. Two thermometers were attached to the rubber bar thermometer *2*, indicated in *Fig. 1*, whose errors did not exceed ·1° F., and whose bulbs were of thin glass and quite sensitive to changes of temperature. The water in the incubator had been exposed to the action of the kerosene lamp for several hours, and the temperature had risen to 105°, or thereabouts. Your committee requested the attendant to set the indicator to maintain a temperature of 101°.

The mercurial thermometers, which may be called III and II for brevity, read as follows during this part of the trial:

Date and Hour, 1885.	Committee Thermometer III.	Condition of Incubator.
October 2d, A M.		
h. m.	degrees.	
9 58·5	105·4	Automatically lowering its temperature to 101° at the request of the committee.
10 12·7	103·8	
10 21 0	102·6	
10 30·3	[illegible]	

The set screws between which the indicator plays to make and break the circuit operating the clock-work were then set by the attendant; the entire apparatus was then tied by the committee with cotton lamp wicking, and sealed in such a way that the lamp, or any part of the apparatus, could not be changed without breaking the seals, except by the self-acting regulating apparatus, and the following observations made:

October 2, 1884.	Committee Thermometer III.	Committee Thermometer II.	Condition of the Incubator.
A. M.			
h. m.	degrees.	degrees.	
10 30·3	101·7	101·1	Automatically keeping its temperature uniform.
10 45	101·6	100·9	
11 11	101·6	100·9	
11 32	101·6	100·9	
11 45	101·6	101·0	
P. M.			
12 50	101·3	100·5	
1 47	101·5	100·9	

During the preceding observations, a change of about ·1° F. in the reading of the thermometers was followed by the operation of the ventilating fans of the incubator. The opening and closing of these fans took place at intervals varying from one-half minute to two minutes, continuously throughout the trial. Your committee then broke the seals and requested the attendant to increase the temperature to about 109°. This being done, the following readings were made during the afternoon and the succeeding morning, when the seals were finally removed.

1884. October 3d and 4th.	Committee Thermometer III.	Condition of the Incubator.
October 3d. P. M.		
h. m.	degrees.	
2 49	109·5	Automatically keeping its temperature uniform.
3 47	109·0	
9 12	108·5	
October 4th, A. M.		
8 33	109·1	
8 37	109·1	

October 4th, 8·40 A. M., temperature of the outside air, 62° F.

The above observations speak for themselves, and your committee is of the opinion that the apparatus as exhibited and with careful adjustment will maintain a uniform temperature to within $\frac{1}{4}°$ F., when the temperature in the incubator is higher than that of the surrounding air.

Respectfully submitted,

LEONARD WALDO, *Sub-Committee.*

REPORT OF DR. LEONARD WALDO, SUB-COMMITTEE OF SECTION XXII, ON THE EXHIBIT OF METALLIC THERMOMETERS MADE BY THE STANDARD THERMOMETER COMPANY, OF PEABODY, MASS.

NEW HAVEN, September 1, 1885.

PROFESSOR M. W. HARRINGTON, *Chairman of Sub-Committee on Registering Meteorological Instruments, Section XXII.*

SIR :—I submit herewith my report to you on the exhibit of the Standard Thermometer Company, of Peabody, Mass., made at your request.

Very respectfully yours,

LEONARD WALDO.

REPORT.

The limitations of mercurial and other thermometers are felt in many of the processes of the arts. The boiling and freezing points of mercury being so near together, and the nature of glass rendering it so fragile, and so liable to softening near the boiling point of mercury, combine to render some substitute for the mercurial thermometer highly desirable in many cases.

Your committee, therefore, with your consent, decided to give as thorough an examination into the performance of the metallic thermometers exhibited, as the limits of an extemporized laboratory would allow.

The exhibited thermometers consisted essentially of a coiled cylindrical spiral, the material of which was composed of laminated brass and steel, united by silver solder.

This cylindrical coil is about 1·5 inches long, about ·6 of an inch in diameter, each coil having a width of ·1 inch, and making about twelve turns throughout its length. A change of temperature will, of course, cause an extension of a free end of such a coil, and this extension is magnified by a rack and pinion, which gears the indicator to the free end of the coil.

As constructed by this company, the apparatus is simple, the adjustment of the hand which serves as an indicator, and which moves over a circular dial, is easily effected, and your committee is of the opinion that the indications would be consistent with themselves permanently, so far as liability to get out of adjustment is concerned.

The hand which serves as the temperature indicator, moves over a clearly graduated dial, and the entire instrument is cased in a metallic box, and made to hang in any position.

Two metallic thermometers were selected for careful examination; they were marked Nos. 22 and 23. The hands moved over the dials smoothly, without hitching and in the open air had the usual agreement with mercurial thermometers hung in neighboring positions which is expected of reputable mercurial thermometers.

A water-comparator consisting of a rectangular box holding several gallons of water and provided with heating and stirring arrangements was rigged up in a neighboring building, and the two metallic thermometers were immersed in the water in connection with a number of precision thermometers. After a thorough agitation of the water, the thermometers were read in such a series that the observer began at the left hand end of the row of thermometers standing in the comparator and read to the extreme right. Then making a second reading at the extreme right, the thermometers were then read in an inverse order. The times at the beginning and end of the entire series being noted and the intervals between the readings of the thermometers being practically the same, it is assumed that the means of the thermometer readings correspond to the mean of the observed times.

This is not rigorously true, since the radiation coefficient of the comparator and of the thermometer is not taken into account. Its accuracy is in keeping with the general accuracy to be attained in such apparatus as we were able to devise during the exhibition. Professor Harrington made the record, and occasionally verified the thermometer readings. Professor Rogers was present during a part of the test.

The standard thermometers inserted in the comparator consisted of two short standards made by Hicks, of London, graduated to ½° Fahrenheit, 1° F. = 1·8 mm. The first thermometer of the two reading up to $+ 40^\circ$ F., and the second reading to $+ 103^\circ$ F.

The corrections of these standards were determined by comparison with the Yale College Observatory standards to be at

Degrees F.	*Degrees F.*
32	0·0
52	0·0
72	+ 0·1
92	0·0

A third standard introduced was one of the standards issued by the Yale Observatory, graduated in C. degrees to $\frac{1}{5}°$ C., and having $1° = 4·7$ mm. It is marked "Yale Observatory Standard 53.," and I am indebted to Mr. O. T. Sherman, of the Yale Observatory Thermometric Bureau, for the following system of corrections to be applied to its scale.

Degrees C.	*Degrees C.*
0	— 0·04
5	— 0·007
10	+ 0·043
15	+ 0.028
20	+ 0·016
25	+ 0·025
30	+ 0·073
35	— 0·130
40	+ 0·074

The following observations were made:

Observed Readings of the Standard Mercurial Thermometers: "W. O. I.," "W. O. II.," "Y. O. 53," in a Water Comparator with the Metallic Thermometers marked "No. 22" and "No. 23."

	Date and Time of Comparison.	Reading of W. O. I.	Reading of W. O. II.	Reading of Y. O. 53. (Centigrade.)	Reading of No. 23.	Reading of No. 22.	Y. O. 53, reduced to Fahr.	Y. O. 53, correction in Fahr. degrees.	W. O. I. and W. O. II., correction.
	1885. October 3d. *h m.*	degrees.	degrees.	degrees.	degrees.	degrees.	degrees.	degrees.	degrees.
1	12 47·8	26·9	. . .	— 2·55	27·8	27·0	27·41	. . .	. . .
	12 51·1	27·1	. .	— 2·50	27·8	27·1	27·50	— 0·06	0·0
2	12 53·4	27·05	. . .	— 2·60	27·9	27·1	27·32	. . .	. . .
	12 56·9	27·15	. . .	— 2·60	27·9	27·1	27·32	. . .	. . .
3	12 58·8	27·15	. . .	— 2·50	28·1	27·3	27·50	. . .	. . .
	1 2·2	27·35	. . .	[— 2·20]	28·2	27·3	[28·04]	. . .	. . .
4	1 3·8	27·4	. . .	— 2·40	28·2	27·6	27·68	. . .	. . .
	1 7·2	27·5	. . .	— 2·40	28·2	27·6	27·68	. . .	. . .
5	1 10·4	27·6	. . .	— 2·15	28·3	27·6	28·13	. . .	. . .
	1 14·2	27·55	. . .	— 2·35	28·3	27·6	27·7	. . .	. . .
6	1 35·9	. . .	38·25	+ 3·55	39·20	38·70	38·39	. . .	. . .
	1 39·7	. . .	38·38	— 3·60	39·20	38·70	38·48	+ 0·08	0·0
7	2 5·1	. . .	68·80	20·40	70·5	68·9	68·72	. . .	. . .
	2 10·2	. . .	68·70	20·40	70·6	68·9	68·72	+ 0·03	— 0·1
8	2 16·5	. . .	68·60	20·34	70·3	68·7	68·59	. . .	. . .
	2 20·1	. . .	68·55	20·30	70·3	68·7	68·54	. . .	. . .
9	4 11·9	. . .	89·40	31·65	91·9	89·0	88·97	. . .	. . .
	4 14·7	. . .	89·10	31·60	91·9	89·0	88·88	+ 0·13	0·0
10	4 15·2	. . .	89·10	31·60	91·9	89·0	88·88	. . .	. . .
	4 18·5	. . .	89·05	31·55	91·9	89·0	88·79	. . .	. . .
11	4 19·0	. . .	89·00	31·53	91·9	89·0	88·75	. . .	. . .
	4 20·3	. . .	89·05	31·50	91·9	89·0	88·70	. . .	. . .
12	4 54·2	. . .	69·05	20·60	72·3	69·2	69·08	. . .	. . .
	4 56·2	. . .	69·05	20·63	72·3	69·2	69·13	+ 0·03	+ 0·1
13	4 57·2	. . .	69·05	20·60	72·3	69·1	69·08	. . .	. . .
	4 59·9	. . .	69·05	20·62	72·3	69·1	69·12	. . .	. . .

Taking the means of each set, and applying the corrections indicated in the last two columns, we have the following table, showing the corrected standard readings in Fahrenheit degrees as compared with the readings of the metallic thermometers, Nos. 23 and 22:

Number of the Pair	Mean of the Times.	Mean of the W. O. Thermometer in Fahr.	Mean of Y. O. 53 in Fahr.	Corrected Mean W. O. Thermometer.	Corrected Mean Y. O. 53.	Mean of the Mercurial Standards.	Mean of No. 23.	Mean of No. 22.
	h *m.*	degrees.	degrees.	degrees.	degrees.	degrees.	degrees.	degrees.
1.	12 49·4	27·00	27·45	27·00	27·3[illegible]	27·2[illegible]	27·80	27·05
2	12 55·2	27·10	27·32	27·10	27·26	27·18	27·[illegible]	27·10
3.	1 0·5	27·25	[27·50]	27·25	27·44	27·35	28·15	27·30
4.	1 5·0	27·45	27·68	27·45	27·62	27·54	28·20	27·60
5.	1 12·3	27·57	27·91	27·57	27·85	27·71	28·30	27·60
6.	1 37·8	38·31	38·43	38·43	38·51	38·47	39·20	38·70
7.	2 7·6	68·75	68·72	68·85	68·75	68·80	70·55	68·90
8.	2 15·3	68·57	68·57	68·67	68·60	68·63	70·30	68·70
9.	4 13·3	89·25	88·92	89·25	89·05	89·15	91·[illegible]	89·00
10.	4 16·5	89·07	88·83	89·07	88·95	89·01	91·[illegible]	89·00
11.	4 19·7	89·03	88·72	89·03	88·85	88·94	91·90	89·00
12.	4 55·2	69·05	69·10	69·15	69·13	69·14	72·30	69·20
13.	4 58·1	69·15	69·10	69·15	69·13	69·14	72·30	69·10

From the above we readily deduce the corrections to be applied to Nos. 23 and 22 to reduce their face readings to the true temperature of the comparator as follows:

Number of Observations.	Point of Ther. Scale F.	Correction to No. 23.	Correction. to No. 22.
	degrees.	degrees.	degrees.
5	27·4	— 0·65	— 0·09
1	38·5	— 0·73	— 0·23
2	68·7	— 1·71	— 0·08
3	89·0	— 2·87	— 0·03
2	69·1	— 3·16	— 0·04

Analyzing the above results, we see that No. 23 fails to return to its agreement with the mercurial thermometers at 70°, after it had been compared at 90°, by 1·4°.

No. 22, however, shows a remarkable agreement with the scale of the mercurial thermometers both ascending and descending. With the exception of its deviation at 40°, which is still less than 1/4° F., there seems to be no deviation of its scale as great as ·1° F.

This, for commercial purposes, is a practical agreement with the perfect mercurial thermometer at ordinary temperatures.

It is not improbable that the coincidence extends in practical agreement with the Fahrenheit scale to some degree above the point of boiling water. On this point, however, your committee has had no opportunity to satisfy itself.

The instruments impressed your committee with their neatness of design and legibility of dial. They seemed peculiarly appropriate for ordinary air temperature use, and have the merit of revealing the temperature at a glance from any point of an ordinary sized room. Your committee was informed that display thermometers of large size were prepared by the same company which were legible at half a block's distance.

Respectfully submitted,

LEONARD WALDO,

Sub-Committee of Section XXII.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XXIX.

(SECTION VIII, CLASS I OF THE CATALOGUE.)

"Educational Apparatus," with which is Incorporated Section XIII, "Apparatus for High Electro-Motive Force."

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, MARCH, 1886.]

PHILADELPHIA:

THE FRANKLIN INSTITUTE.

1886.

EDITING COMMITTEE.

1884–INTERNATIONAL ELECTRICAL EXHIBITION–1884

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXIX.—EDUCATIONAL APPARATUS.
SECTION XIII.—APPARATUS FOR HIGH ELECTRO-MOTIVE FORCE.

To the Board of Managers of the FRANKLIN INSTITUTE:

GENTLEMEN:—I have the honor to transmit herewith the report of Examiners of Sections XXIX and XIII, on "Educational Apparatus," and "Apparatus for High Electro-Motive Force."

Respectfully,
M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, February, 1886.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—I herewith hand you the report of Section XXIX, on "Educational Apparatus."

Respectfully,
A. E. DOLBEAR,
Chairman Section XXIX.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—I herewith hand you the report of Section XIII, on "Apparatus for High Electro-Motive Force."

Respectfully,
J. B. DEMOTTE.
Chairman Section XIII.

GREENCASTLE, IND., December, 1885.

REPORT ON EDUCATIONAL APPARATUS.

EXHIBIT OF JAMES W. QUEEN & CO.

The general exhibit of this company was of much greater variety than that of any other exhibitor, and embraced useful devices for illustration and demonstration in nearly the whole field of physics.

The attention of the committee was directed chiefly to the specific electrical apparatus useful for educational purposes, as distinguished from instruments of precision; which latter department was in the hands of another committee. A very large part of experimental philosophy is quite independent of the question "How much?" and in the dominion of electricity it is particularly the case that the phenomena may be developed, and the relations studied without any attempt towards quantitative results.

Messrs. Queen & Co. were instrumental in securing a large number of foreign exhibitors, whose apparatus was shown in the space allotted to them.

A part of many of these separate exhibits consisted of apparatus properly called instruments of precision, and referably going to that examining section. Because in many institutions of learning to-day, measuremental work of the highest grade is done, and it is difficult to draw a line between instruments adapted to such work and what is ordinarily understood by the term Educational Apparatus; and on the other hand, the skilful teacher is able to do some very fair quantitative work with instruments designed only for indications.

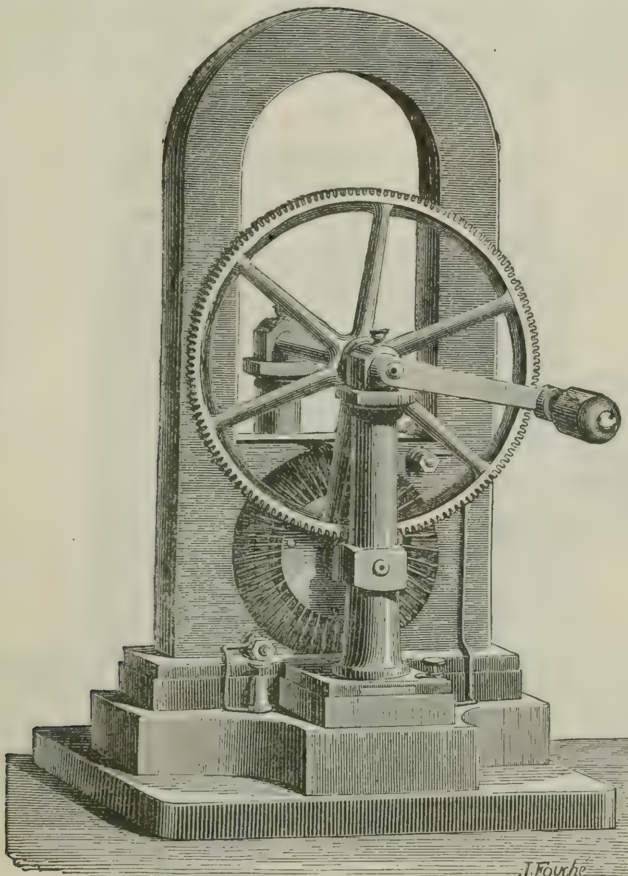
It has been thought best to incorporate into this report the special reports on hand dynamos, by Prof. W. A. Anthony, of Cornell University, and by Lieut. Murdock, U. S. A.

Queen & Co.'s Exhibition Catalogue contained upward of 1,600 numbers. The committee could not inspect them all but everything they specifically looked for, they found. The following they deemed worthy of special mention.

EDUCATIONAL APPARATUS BY BREGUET.

Gramme Machines.—The structure and principles of the Gramme machine are so well known that a description of them is not thought to be necessary here. They are compact, exceedingly

simple in structure, easily managed, and very efficient. A number of these of different sizes, and adapted to be run by hand or by the steam engine, were exhibited. The smaller ones to be run by hand

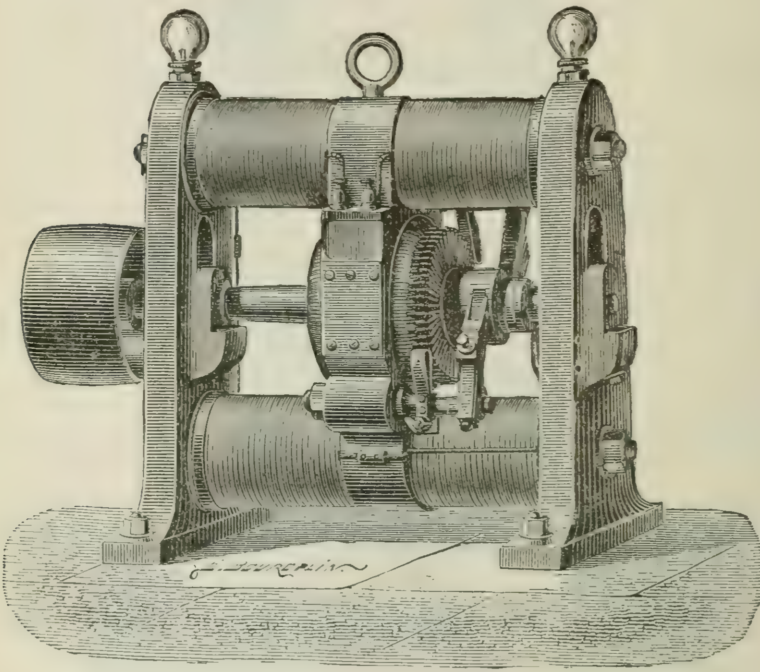


No. 16. Gramme Magneto-Electric Machine.

are provided with powerful permanent magnets to furnish the magnetic field, and such ones may be used as substitutes for a small galvanic battery, and a large number of experiments may be performed with the current from such a machine. The machine may have armatures wound with coarse or fine wire, or what is better, have both. One may then have a high electro-motive force, or a low electro-motive force, adapted to his needs. With the machine made for laboratory model and with thick wire armature, one may

produce about ten volts and two and one-half ampères current with a speed of 2,640 revolutions per minute.

With the fine wire armature, one may have about forty volts at the brushes, and a current of five ampères. As the electro-motive force is proportioned to the speed, each machine has a numerical constant which, multiplied by the number of revolutions per minute, will give the electro-motive force.



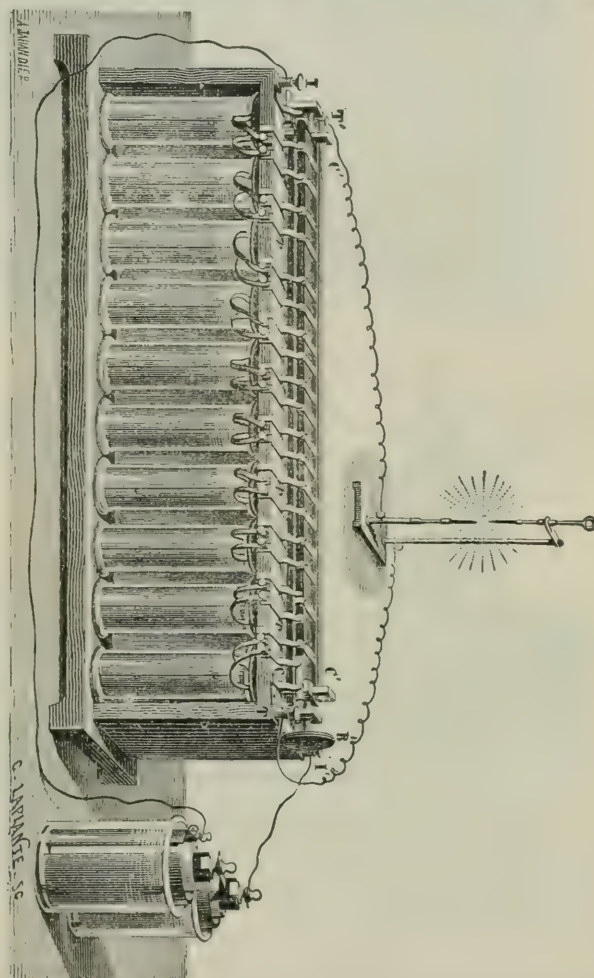
Gramme Machine. Type A.

The large machine, marked Type A, requires an engine of two or three horse-power, to run with any speed on a circuit. It is particularly well adapted to the needs of workshops, and of institutions of learning, for demonstrative requirements seldom exceed its capabilities. With a speed of 1,000 revolutions per minute, the electro-motive force is seventy-five or eighty volts, and the current strength about twenty-five ampères, while with a speed of 1,200 or 1,400 one may run three arc lights or twenty or thirty incandescent lamps. With lower speeds and less current all the demonstrative

work necessary for instruction may be done in a very much more satisfactory way than is possible with any kind of a galvanic battery.

The exhibit of the Maison Breguet included many other scientific instruments of value for educational purposes.

There was shown the well-known Serrin electric regulator and the Planté secondary batteries. Of these last, there was a set of

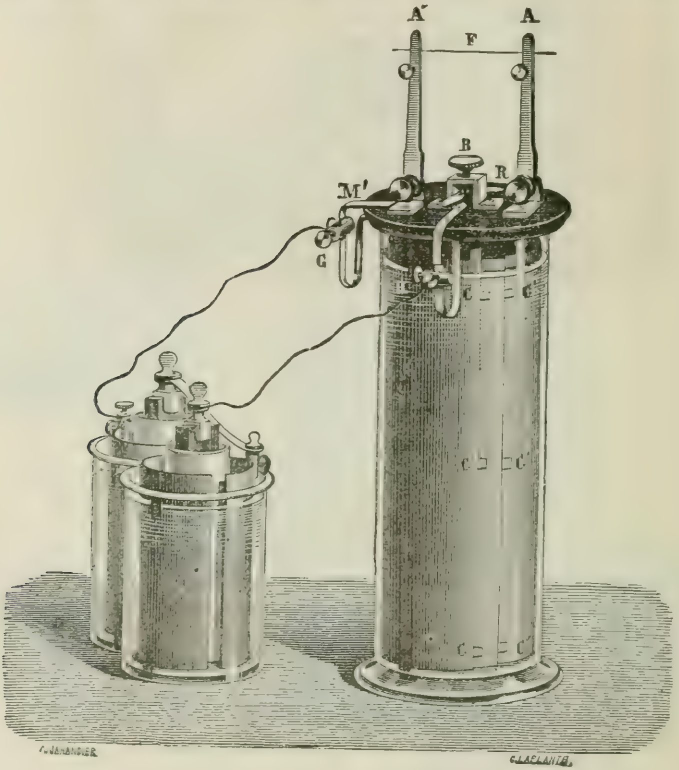


Set of Twenty Small Secondary Batteries.

twenty elements exhibited, and also several different sizes of single elements. These are useful batteries for class demonstration, and for general lecture experiments.

The rheostatic machine and battery of secondary couples, with zinc wire of M. Gaston Planté.

This machine is composed of fifty condensers in mica, joined to a Planté commutator by metallic spring blades, or springs, in such a manner as to be successively charged in quantity and discharged in tension. The two poles of the electric source which should charge the apparatus are joined permanently

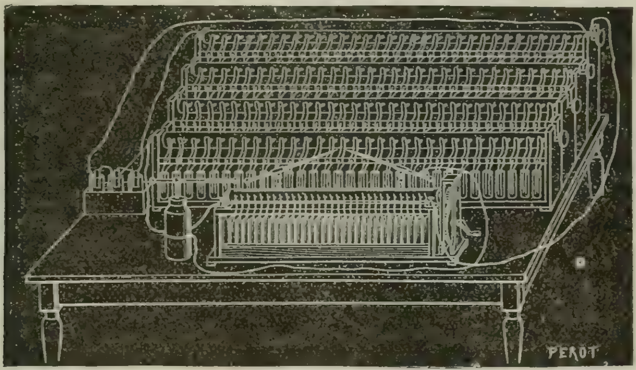


Planté's Secondary Battery.

to the binding screws *P P*, whilst the sparks burst out between the points represented in cut. This spark, or flash, is in proportion to the electro-motive force of the charge. Its length has a maximum for each apparatus, which maximum is determined by the construction.

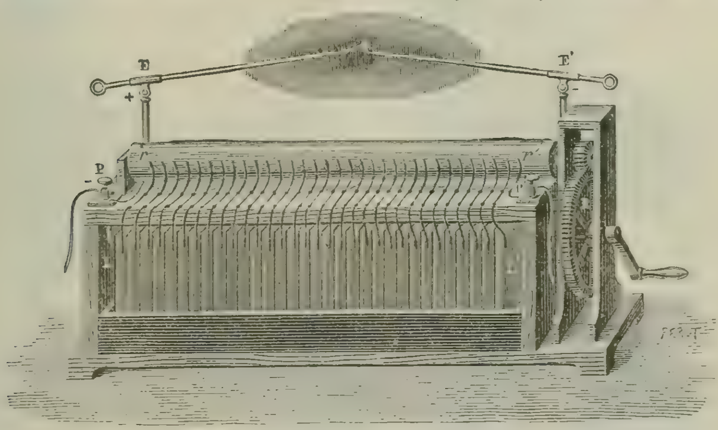
The complete battery is formed of 320 of these small elements, divided in four batteries of eighty couples each. These eighty

couples can be associated instantly by means of the commutator Planté, in quantity or in tension. These four batteries, laid out on shelves, one above the other, to put each couple in action are associated in quantity for the charge, and in tension for the discharge.



Rheostatic Machine (Breguet).

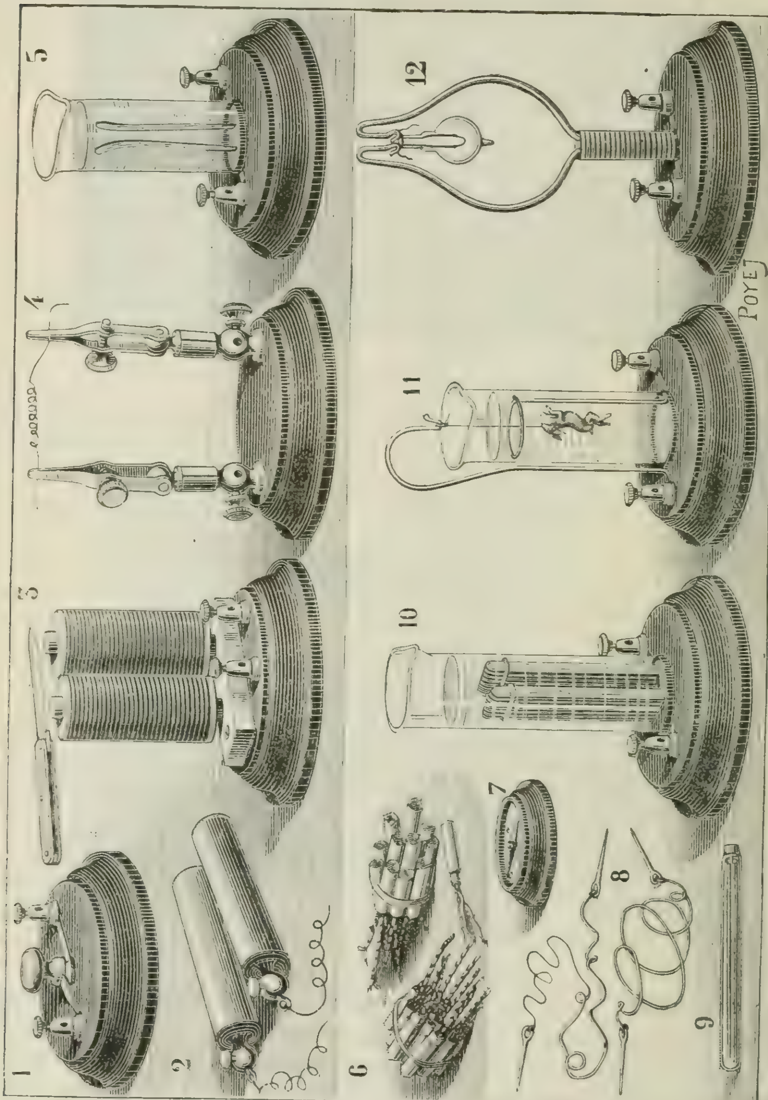
Apparatus by Gerard.—Dynamos of various sizes, to be run by hand or steam-power. These machines are very compact, and those to be worked by hand are good substitutes for batteries for the many experiments needing a tolerably steady current, but not



Rheostatic Machine (Breguet).

great current strength. A small one tested gave, when run with one hand and small pulleys, an electro-motive force of fifteen volts and a current of five ampères, and developed magnetism in an electro-magnet to such an extent that one could not pull away the

armature while a current was passing. These small hand dynamos of Gerard are intended for school work, and small incandescent lamps, electro-magnets, electric bells, fuzes for explosion, etc., form a part of the collection, all adapted to be run by the current generated by hand, and they work successfully.



Accessories to Small Gerard Machine.

In order to exhibit, with satisfaction, electrical phenomena, it is more than convenient, it is necessary, that the different pieces to be used should be adapted to each other, which is not always the case when pieces are obtained without regard to adaptation, as is often the case with school apparatus. Gerard, therefore, has a series of accessories for his machines, some of which are shown in the accompanying cut, which mostly tell their own story, and show to what a variety of experiments the machine may be put.

(See reports following on hand dynamos, by Professor Anthony and Lieutenant Murdock.)

It is not an uncommon thing for comparisons to be made between hand dynamos and galvanic batteries, in which the statement is that a certain machine is equal to two or five or ten Grove cells. Such a statement is very indefinite indeed, and not a few have bought such machines expecting to get much more from them than is mechanically possible. The following exposition of the relations between such machines and the work spent on them may help one to a more correct idea.

Suppose a man to exert a constant power equal to one-tenth of a horse-power in running a dynamo in a circuit in which the total resistance is R ohms. To find the electro-motive force produced: the horse-power for a certain current is $HP = \frac{E\,C}{746}$

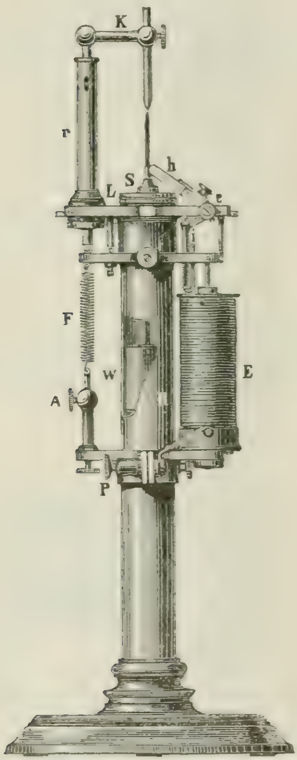
$$\text{As } C = \frac{E}{R} \;\therefore\; HP = \frac{E^2}{746\,R} \;\therefore\; E = \sqrt{HP \times 746\,R}.$$

If $HP = \frac{1}{10}$	$R = 2$	$E = \sqrt{149{\cdot}2} = 12{\cdot}2$ volts.
" " "	$R = 5$	$E = \sqrt{373} = 19{\cdot}3$ "
" " "	$R = 10$	$E = \sqrt{749} = 27{\cdot}3$ "
" " "	$R = 50$	$E = \sqrt{3730} = 61{\cdot}$ "
" " "	$R = 100$	$E = \sqrt{7460} = 86{\cdot}4$ "

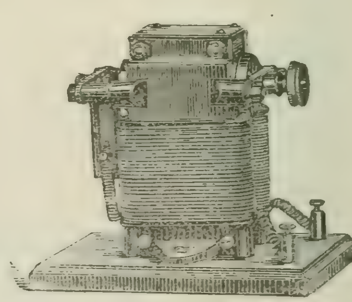
Now, one-tenth of a horse-power is more than most persons can exert except for a brief time, but the current strength for sixty-one volts and resistance fifty ohms will be but 1·22 ampères. How much of this energy will be available will depend upon the ratio of the external to the internal resistance of the machine. Hence the necessity for having the apparatus to be used with such a hand dynamo, *adapted to it.*

EXHIBIT OF C. & E. FEIN, OF STUTTGART.

Dynamos for hand working. These were conveniently and neatly mounted upon tables, and provided with numerous attachments suitable for use in the lecture room. The exhibited set of accessories was more complete than any other exhibit of similar kind, and embraced nearly everything which a teacher would want in teaching this subject. The pieces were generally of a larger size than those by other makers.



Fein Arc Lamp.



Fein Electromotor.

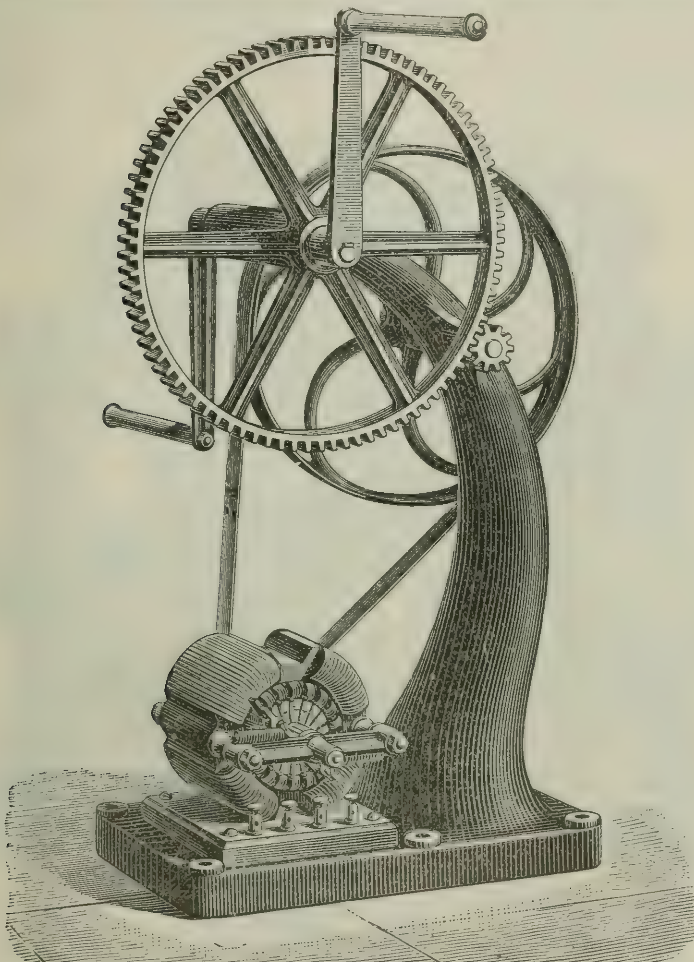
The following pieces were specially noticed:

Voltameter, electro-magnet, galvanoplastic apparatus, electromotor induction coil, incandescent lamps, arc lamps, Geissler tubes, voltameter and ampèremeter. These appeared to be all well made and adapted to their specific uses.

(See report on hand dynamo of Fein, by Lieut. Murdock.)

EXHIBIT OF A. DE MERITENS, OF PARIS.

His dynamos are made in large models for supplying currents for electric lights, or for any other purpose, and require some motive-power as steam or water; and small models which may be

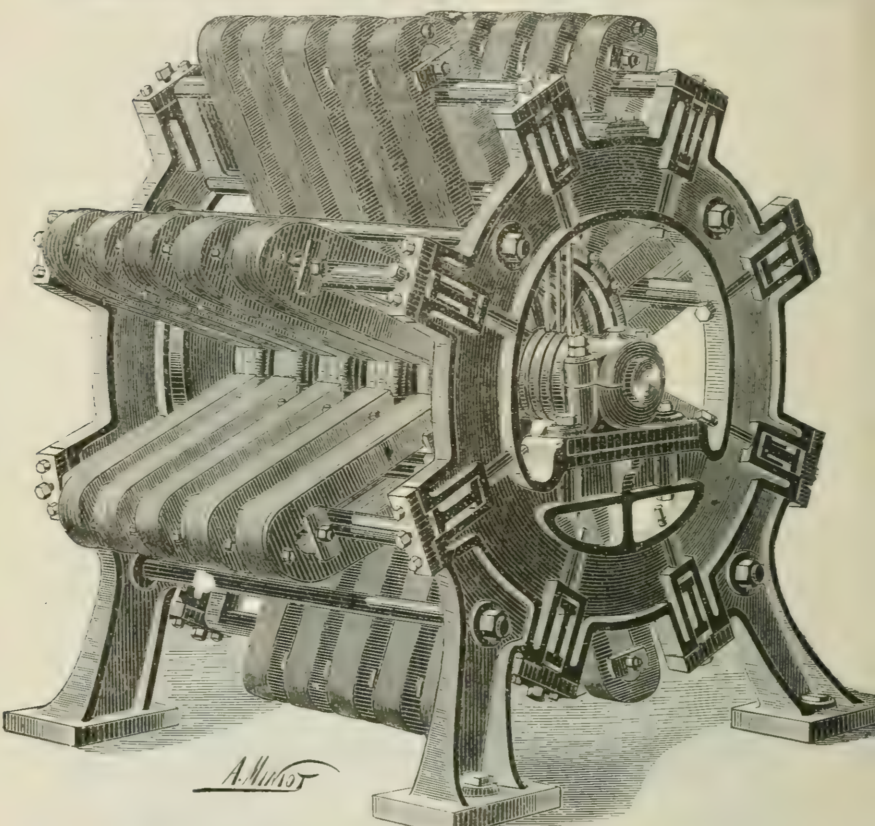


De Meritens' Machine. Model C.

run by hand-power, and suitable for most lecture-table experiments. The cut represents such a machine mounted to be driven by either one or two persons, and is capable of producing an arc light. The machine is so arranged that armatures with different

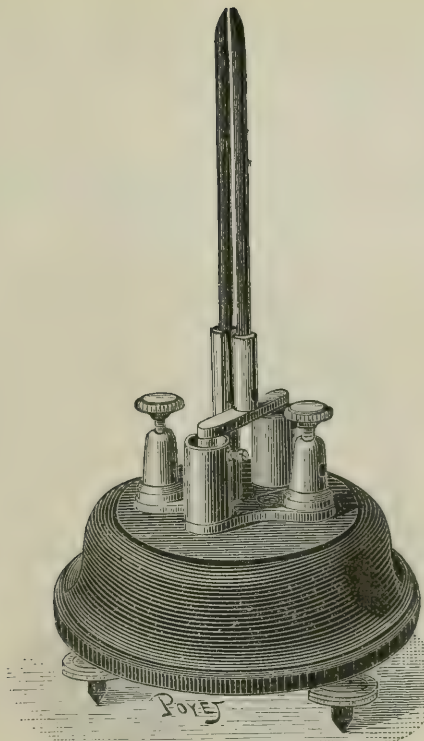
resistances may be readily substituted, and thus adapted to different kinds of electrical work. The dynamos are particularly compact and efficient. Several are already in use in colleges in the United States.

There was also exhibited a large magneto-electric machine, by De Meritens, driven by an engine. It was an alternate current machine, and was used to light Queen & Co.'s exhibit, with Jablochkoff candles, and was an interesting machine for both



De Meritens' Alternating-Current Machine.

structure and function, as such machines are not used to any extent in this country, and the Jablochkoff candles requiring such alternating currents, are now-a-days mostly displaced by the more modern arc and incandescent lamps. This machine, marked Model A, was capable of lighting thirty Swan lamps.



Jablochkoff Candle.

There were various interesting accessories to the exhibit of De Meritens,—brackets, commutators, Jablochkoff candle holders, globes, etc., exhibiting both taste and mechanical skill.

(See Prof. Anthony's report on De Meritens' hand dynamo.)

TEST OF HAND DYNAMOS.

At the request of Messrs. James W. Queen & Co., I tested some of the hand dynamo machines for which they are agents. The attempt was made at first to use ordinary instruments, tangent and potential galvanometers, but it was found that the irregularity of the current prevented any accurate observations, and it was impossible to turn the cranks with sufficient regularity to produce a current which could be measured. The plan was then adopted of measuring the external resistance, and determining the current by a Deprez ammeter. The resistances used were of German-silver,

several being attached to the frame of one of the Fein machines. Three others, each of about six ohms resistance, were used.

It was thought that the best method of testing would be to obtain as far as possible, the maximum output of the machines, and the observations were therefore made under these conditions. The crank was turned as rapidly as possible, and the maximum current was observed. The results thus obtained, were of course higher than could be kept up for any length of time, but in most of the machines the test was also made under the usual working conditions.

The two when combined give the maximum which can be obtained, and the ordinary work which can be depended on.

The resistances heated very slightly, owing to the short time that the current was passed through them.

The ammeter used had been calibrated at the test house and found to be in general in excess about three per cent. This correction was applied to all observed currents. Currents below two and one-half ampères were measured by another ammeter, graduated to tenths of an ampère. No correction was applied to the readings of this instrument.

The above applies to all machines tested.

Two machines were exhibited by C. & E. Fein, the No. 3 and No. 10.

The No. 3 gave the following results:

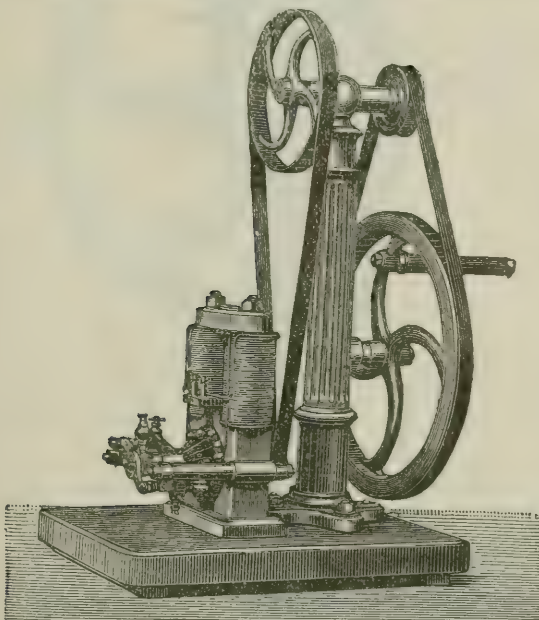
Armature Resistance,	35
Field "	26
Total,	61 legal ohms.

Current.	External Resistance.	Difference of Potential.	Total Resistance.	E. M. F.
10·5	·9	9·45	1·5	15·75
10·1	1·1	11·1	1·7	17·2
8·9	1·5	13·3	2·1	18·7
7·6	1·85	14·1	2·45	18·6
6·5	2·8	18·2	3·4	22·1
3·7	5·0	18·5	5·6	20·7
1·65	7·3	12·0	7·9	12·9
1·25	8·9	11·1	9·5	11·9
·50	14·4	7·2	15·0	7·5

The results may be taken as the best capable of being obtained by a man of average strength. The best continuous working is about one-half the above E. M. F. for any given resistance.

The makers make the following statement in regard to the capacity of this machine.

It is capable of melting a steel wire 250 mm. long and ½ mm. thick. It will make a platinum wire of 500 mm. in length, and ½ mm. thick, incandescent. It will evolve 150 cubic cm. of

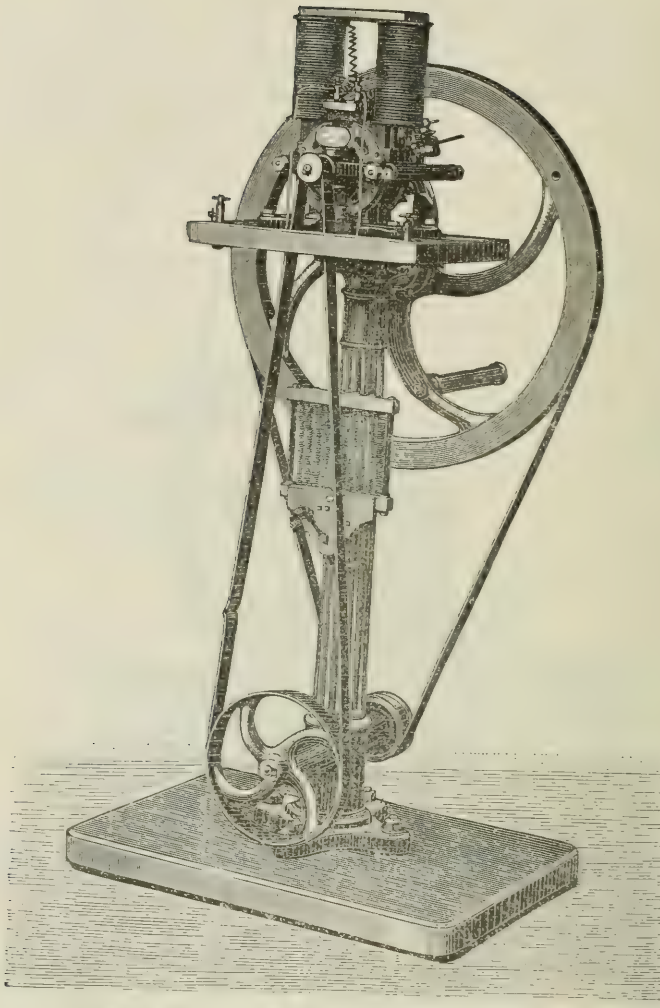


C. & E. Fein's Hand Dynamo. (No. 3.)

water gases per minute. It will deposit 280 milligrams of copper per minute.

The arrangement of this machine appears to be good, and quite compact, with but small weight for its power.

The second machine, exhibited by C. & E. Fein, was a No. 10, Model 1 b. This machine was the most powerful one tried, and was operated by two men on separate cranks. It has attached to its frame a set of German-silver resistances, which affords the means of modifying the external circuit at will. Some difficulty was found at first in exciting the field, but when the machine once



C. & E. Fein's Hand Dynamo. (No. 10.)

worked it gave very good results. The same method was pursued in obtaining the maximum output. The results were as follows

Armature resistance, ...	6·32
Field "	8·82
	15·14 legal ohms.

	Current.	External Resistance.	Difference of Potential.	Total Resistance.	E. M. F.
	4·9	·9	4·4	16·0	78·4
	4·8	1·1	5·3	16·2	77·8
	4·9	1·5	7·3	16·6	81·3
Maximum	4·0	8·9	35·6	24·0	96·0
work with	3·7	15·7	58·1	30·8	114·0
two men.	3·6	22·3	80·3	37·4	134·6
	3·3	28·6	94·4	43·7	144·
Continuous working, two men.	2·0	28·6	57·2	43·7	87·4

As illustrating the uses of machine No. 10, the maker states that it will melt a steel wire 1 metre long and 0·15 mm. thick. It will make incandescent a platinum wire 2 metres long and 0·15 mm. thick, and it evolves 150 cubic centimetres of gas per minute. It will deposit 250 milligrams of copper per minute.

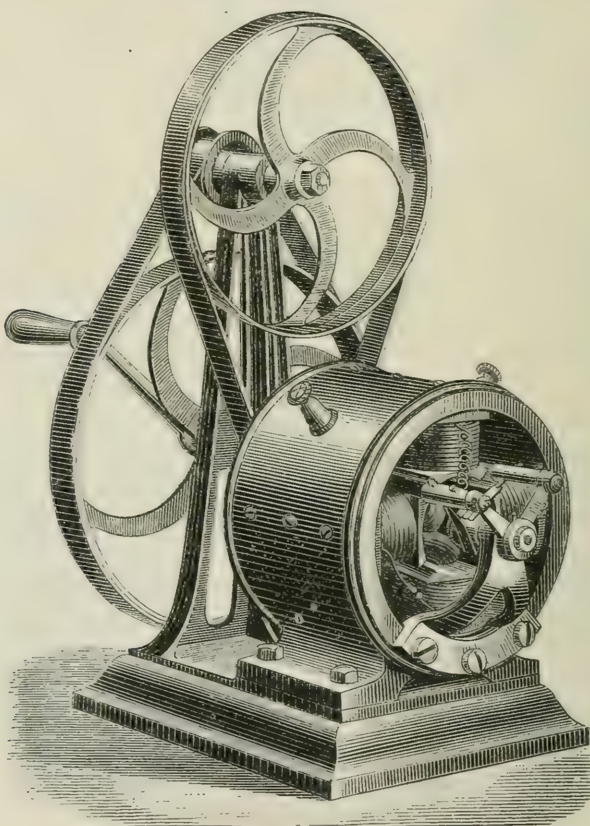
This machine is of such capacity as to admit of demonstrating almost anything which can be expected of a dynamo machine. As it is capable of being worked by two men, its output is very large, and as seen by the figures of the test, it would bring to normal incandescence for a short time five ordinary Edison lamps, and would maintain several lamps of low potential, when worked continuously by two men.

The preceding machines are made wound with either coarse or fine wire. No. 3 machine tested, was wound with coarse wire, and No. 10 with fine wire.

Another machine tested was a Magneto-Gramme machine, from the Maison Breguet. It differed materially from the others apart from its being a magneto machine, in having a very small internal resistance, which would adapt it to a very different class of experiments.

Current.	External Resistance.	Difference of Potential.	Total Resistance.	E. M. F.
10·4	·95	9·88	1·01	10·50
9·2	1·15	10·58	1·21	11·13
7·1	1·55	11·00	1·61	11·43
5·4	1·85	9·99	1·91	10·31
4·7	2·75	12·92	2·81	13·21
2·4	5·05	12·12	5·11	12·26
1·75	6·40	11·20	6·46	11·31
1·30	7·90	10·27	7·96	10·36

No attempt was made to preserve a constant speed. One man turned the crank as rapidly as possible, and the maximum current was noted.



No. 2, A. Gerard Dynamo-Electric Machine.

Another machine tested was the Gerard, laboratory model, No. 0, with pulley and crank. This showed much less power than the others, being tested in the same way, with the following results:

Armature resistance,	1·32
Field "	4·93
Total internal resistance,	6·25

Speed.	Current.	External Resistance.	Difference of Potential	Total Resistance.	E. M. F.	
2,600	3·5	·85	3·0	7·10	24·90	Maximum
2,700	1·4	7·15	10·	13·4	18·80	"
3,500	1·0	13·75	13·8	20·0	20·0	"
3,200	·5	20·55	10·28	26·8	13·4	"
2,300	·7	7·15	5·	13·4	9·4	Easy working.
1,900	·3	13·75	4·1	20·0	6·0	"
	·25	20·55	5·1	26·8	6.7	

Reported by
J. B. Murdock.

Report upon Small Machines (dynamos), submitted by James W. Queen & Co., and Tested at the Physical Laboratory of the Cornell University, in January, 1885.

APPARATUS USED.

(1.) *Power Measurements.*—It was at first proposed to place the machines on a small Brackett cradle, but, as the adjustment consumes considerable time, it was thought best to use, as a motor, a Gramme machine, constructed ten years ago at the University, and which is mounted permanently on a very delicately balanced cradle. Having at hand a ten-light Weston dynamo, used for lighting the University campus, it was easy, using this as a generator, to obtain from the Gramme, as a motor, any power required, up to five or six horse-power. The Weston ten-light machine was provided with an adjustable resistance for the field circuit, which gave the most complete control of the current generated, and, therefore, of the speed of, and energy transmitted

by, the Gramme. Under these conditions, the Gramme was a very easily managed and exceedingly delicate transmitting dynamometer. The speed of the Gramme was indicated continuously by a Buss "Tachymeter," but was also frequently taken by a speed counter, as well as the speed of the machine under test.

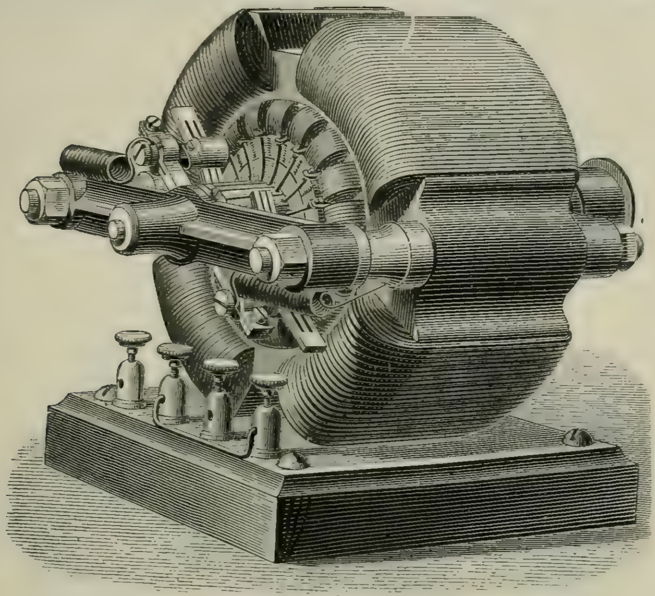
(2.) *Current Measurements.*—The currents were measured by a tangent galvanometer, whose conductor was a turned brass ring, fifty centimetres diameter, and a Thomson graded galvanometer. As H was not accurately known for the position of the tangent galvanometer, the constants of the instruments were determined by the copper voltameter. In the experiment for this purpose, two voltameters were placed in series, and the current continued for 100 minutes. Readings of the galvanometers were taken every four minutes. The extreme deflections were $40° 24'$ and $41°$ for the tangent, and 31·6 and 32·7 for the Thomson. The deposit of copper was, in one cell, 10·477 grammes; in the other, 10·479 grammes; giving for the tangent galvanometer, 6·15; for the Thomson galvanometer constant, ·1644.

(3.) *Resistance Measurements.*—Resistances were measured by means of a dial pattern resistance box, by Elliott Brothers, adjusted to B. A. ohms. Resistances have not been reduced to legal ohms. The machines were run on a dead resistance of German-silver wire wound on a reel, and so connected that it formed one branch of a Wheatstone's balance, the other branches of which could not be appreciably heated by the current. By this arrangement, the resistance could be measured at any time while the current was flowing.

(4.) *Potential Measurements.*—The potentials between the terminals of the machines were measured by means of a Thomson potential galvanometer checked by an Ayrton and Perry voltameter. The constants of both these instruments were determined at the same time as the constants of the current galvanometers, by noting the deflection when they were connected to each side of the German-silver wire, whose resistance was determined while the current was passing by the means described above. In these measurements the power may be considered accurate to about $\frac{1}{100}$; current to about $\frac{1}{100}$; resistance to about $\frac{1}{300}$; potentials to about $\frac{1}{100}$.

The readings of the various instruments during any test were generally very constant. If any considerable variations occurred,

the test was repeated. Computations have been made independently by two persons, and it is believed that the results given are free from errors. In the tests of the machines, they were run at what was supposed to be the normal speed for some time, until instruments gave uniform readings, then readings were taken each minute for ten minutes. The resistance in the external circuit was then changed and another set of readings taken. Below are given the general results of the observations:



De Meritens' Dynamo.

Small De Meritens' Machine.—Shunt wound, armature of the Gramme type.

Weight of machine, ...	68 pounds.
Resistance of armature, ...	1·36 ohms.
" " field, ...	70·7 "

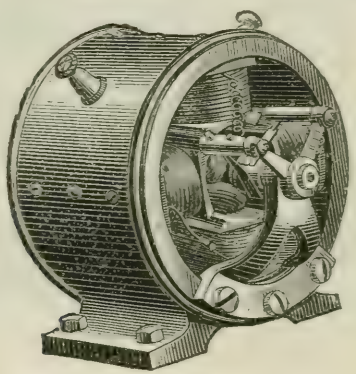
Current $= C.$	Potential at Terminals $= E.$	External Resistance $= R.$	Energy in External Circuit $= C E.$	Power given to Machine $= W.$ (Watts.)	Commercial Efficiency $= \frac{C E}{W}$	Revolutions per Minute.	Power Consumed $HP.$
6·88	49·4	7·18	339·9	686·5	49·5	3,240	·92
6·54	37·1	5·67	242·6	553·9	43·8	3,200	·74
5·56	21·8	3·9	121·2	401·3	30·2	3,300	·54

It will be noted that this machine gave the greatest current with the greatest external resistance. The strength of field therefore diminished as the external resistance diminished. Possibly, better results as to efficiency might have been obtained with a still greater resistance.

The machine worked a Foucault lamp very well, but in order to start the lamp it was necessary to carefully separate the carbons by hand, as, with the small external resistance existing when the carbons were in contact, the machine would not excite itself.

NO. 230. CATALOGUE OF QUEEN & CO.

Small Gerard Machine, No. O[5].—Shunt wound, armature of our pole pieces projecting radially from the axis. On each pole piece was a coil of wire. The commutator flashed badly at high speeds. Twenty-five hundred revolutions per minute was the highest speed it could safely run.



Gerard Dynamo Machine. (No. o[5].)

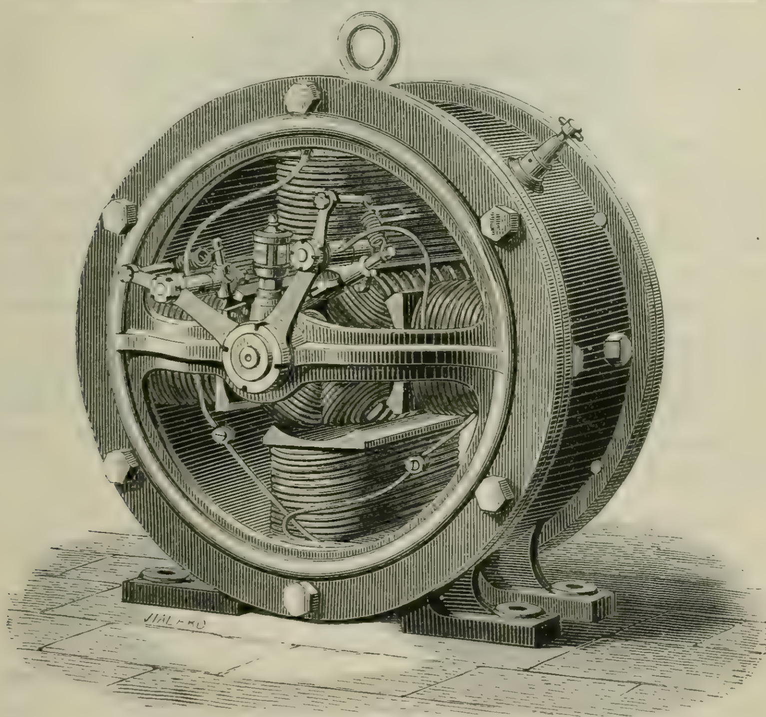
Weight of machine, ... 47 pounds.
Resistance of armature, ... ·199 ohms.
" " field, ... 17·88 "

Current	Potential at Terminals	External Resistance	Energy in External Circuit	Power given to Machine	Commercial Efficiency	Revolutions per Minute.	Power given to Machine in
= C.	= E.	= R.	= C E.	= W. (Watts)	$= \frac{C\ E}{W}$		HP.
4·09	29·04	7·1	118·8	381·2	31·2	2,350	·511
5·33	31·08	5·85	165·7	433·3	38·2	2,590	·581
7·33	28·62	3·9	209·8	433·3	48·4	2,500	·581
7·73	21·8	2·82	168·5	426·4	39·5	3,330	·572
Brushes readjusted and tension of springs increased.							
5·154	36·6	7·1	188·6	556·3	33·9	2,670	·745

Large Gerard Machine No. 3.—Construction similar to small machine.

Weight,	327	pounds.
Resistance of Armature,	·24	ohms.
" " Field,	11·96	"

Current.	Potential at Terminals.	External Resistance.	Energy in External Circuit.	Power given to Machine.	Commercial Efficiency.	Revolutions per Minute.	Power given to Machine in
C.	*E.*	*R.*	*CE.*	*W.* (*Watts.*)	$\frac{CE}{W}$		*HP.*
10·76	80·66	7·94	867·9	2,585	33·6	1,356	3·47
10 39	71·3	6·86	740 8	2,443	30·3	1,390	3·27



Gerard Dynamo Machine. (No. 3.)

To determine how much of the loss in this machine was due to friction and how much to induced currents in the mass of the mag-

nets and armature, the brushes were thrown back and the machine driven at the same speed as in the above experiments. When the field was unmagnetized the power required was 147 watts = ·2 horse-power.

When field was magnetized by another machine having a potential of fifty-four volts, about three-fourths the potential of the Gerard machine, when magnetizing its own field, the power consumed was 830 watts or 1·11 horse-power.

In the circular describing the above machine, the normal speed was given as 1,600. In my experiments, at any speed above 1,400, the flashing at the commutators was so great as to endanger the machine. Below 1,400 there was no flashing and the machine ran quite smoothly.

WILLIAM A. ANTHONY.
Profr. of Physics, Cornell University.

Report upon Small Motors Tested at the Physical Laboratory of the Cornell University, in January, 1885.

These motors were submitted by James W. Queen & Co. from their exhibit at the Electrical Exhibition. They were a Griscom motor, a small motor of English manufacture, name not given, and an Ayrton & Perry motor. The power measurements of the first two were made by mounting the motor on a small Brackett cradle and causing it to drive a small machine which offered a resistance that could be varied at pleasure.

Current was measured by the Thomson current galvanometer, its needle in the most sensitive position, and potential by Siemens torsion galvanometer. The constants of these instruments were determined as described in the report on dynamos.

Griscom Motor.—

Weight, ... about 2½ pounds.
Resistance of field, ... ·616
" " armature, ... ·395

C.	*E.*	*E C.*	*W.* in Watts.	Eff.	Revolutions per Minute.	*W.* in *HP.*
3·81	7·84	29·87	6·86	23·	2,740	·0092
4·28	10·80	46·22	14·84	32·1	5,100	·0199
4·25	10·74	45·64	16·	35·	4,720	·0214
4·57	10·17	46·48	14·21	30 6	3,780	·0191

In this table and those that follow—

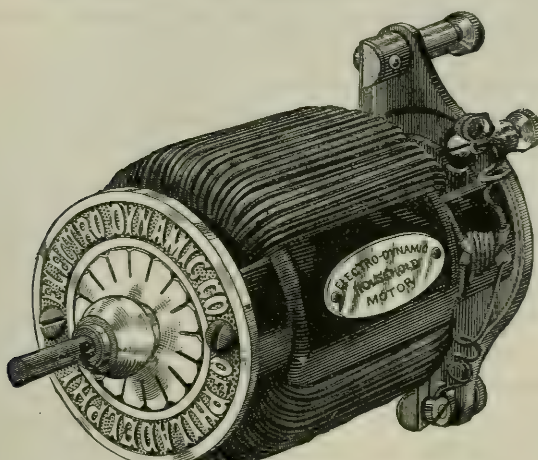
C = current through motor in ampères.

E = difference of potential between terminals.

CE = electrical energy supplied to motor in watts.

W = work delivered by motor in watts.

The other columns explain themselves. In the first experiment recorded above, the potential 7·84 volts, was supposed to be less than the normal potential for the motor. In the subsequent experiments a higher potential was therefore used.



Griscom Motor.

The motor ran during all the experiments very smoothly without sparking at the commutator, and without undue heating.

NO. 353, CATALOGUE OF QUEEN & CO.

S. P. Thompson Motor.—

Weight, ...

Resistance of field, ... ·47 ohms.

" " armature, ... ·373 "

C.	*E.*	*E C.*	*W.* in Watts.	Eff.	Revolutions per Minute.	*W.* in *HP.*
5·33	9·664	51·51	13·55	26·3	2,333	·0182
4·74	10·29	48·77	13·19	27·0	3,360	·0177
4·11	11·49	47·22	19·72	41·8	4,320	·0264
3·865	8·74	33·78	13·50	40·	3,000	·0181

Some trouble was experienced in keeping the brushes of this motor in the best order. It was only by frequent readjustment that so good work, as is shown by the above table, was obtained.

A commutator and brushes, well constructed, would make of this a very useful motor.

NO. 322, CATALOGUE OF QUEEN & CO.

The Ayrton & Perry Motor, submitted by Queen & Co., was tried, but before any considerable power could be obtained from it, the commutator caught fire and made it necessary to stop the machine. It was taken apart, put in the best order possible, without reconstructing it, and tried again. Again the commutator took fire, before anything like the capacity claimed for the motor had been reached. Two similar motors, belonging to the University, had been tried some months before with similar results. The commutator of one of these, said by the makers to be good for a potential of 100 volts, had been partly reconstructed in the University workshop. The spaces between the commutator strips had been filled with insulating material and the brushes remodelled. The armature also had been carefully balanced.

In this condition it was a far better machine than as it came from the makers. It was tested in place of the machine submitted by Queen & Co., and the results are given in the table below, as showing the best that can be expected from this motor, without a radical change in its construction. A higher electro-motive force and higher speeds were tried, but with these there was a continuous flame at the commutator.

Weight of motor, ...	38 pounds.
Resistance of field, ...	0·57 ohms.
" " armature, ...	1·92 "

C.	*E.*	*E C.*	*W.* in Watts.	Eff.	Revolutions per Minute.	*W.* in *HP.*
8·34	59·75	498·32	141·9	28·5	1,500	·19

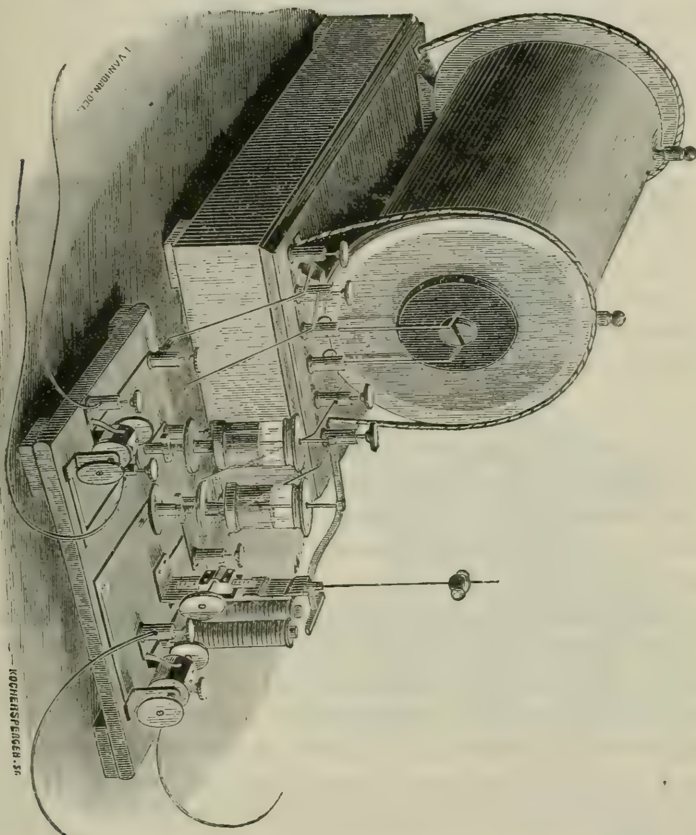
It should have been stated that the power delivered by this motor was measured, by making it drive a dynamo mounted on a Brackett cradle. The current of this dynamo could be perfectly controlled and, therefore, the power which it absorbed could be regulated at pleasure.

WM. A. ANTHONY,
Profr. of Physics, Cornell University.

EDUCATIONAL EXHIBIT OF J. CARPENTIER, OF PARIS.

J. Carpentier is the successor of the renowned Ruhmkorff, and the apparatus exhibited was in every way creditable for both manufacture and performance. The variety was great, and the following pieces were especially noted.

A large inductorium, capable of giving a spark in air of about twenty inches in length. The primary wire of this coil was formed of 403 turns of copper wire, 2·5 mm. in diameter, and having a

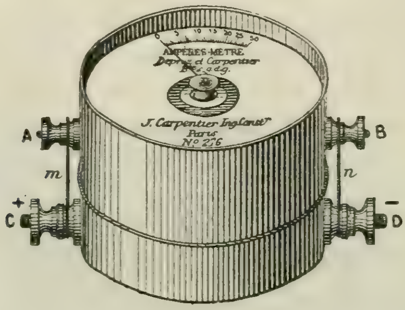


Induction Machine (Carpentier).

resistance of ·25 of an ohm. The secondary wire consisted of 102,500 turns of No. 34 copper wire, equal to about thirty-seven miles, and had a resistance of 58,000 ohms. It required a current of about twenty-five ampères in the primary to give a spark twenty inches long. It could be worked with slow or rapid vibrators, which were mounted upon the base or either side of the coil.

Voltameters and ampèremeters, of Carpentier and Deprez pattern. These, aside from being as accurate as others, are considerably cheaper.

Electrometer of Mascart.



Ampèremeter (Carpentier.)

Deprez electric motors.

Apparatus, of Melloni, with many accessories, and the Clamond thermopiles, which give with a gas flame an E. M. F. of about one-fiftieth volt per pair.

APPARATUS OF EDELMANN.

The most of the apparatus exhibited by this maker was intended for accurate electrical measurements and original research. Some of the voltameters and ammeters for student's use are cheap, but good. A Wiedemann galvanometer was used in the test house of the Exhibition.

The attention of the committee was called to Edelmann's "Physikalisches Arbeitsstatif" or universal stand with heavy tripod. This is a very neat and convenient laboratory instrument, and is supplied with a great number of clamps and pincers, and attachments or fitting up apparatus in scientific lectures. Edelmann also exhibited quite a collection of reading telescopes, galvanometers, and a very neat model of Wheatstone's bridge, after von Beetz.

APPARATUS OF ELLIOTT BROTHERS, LONDON.

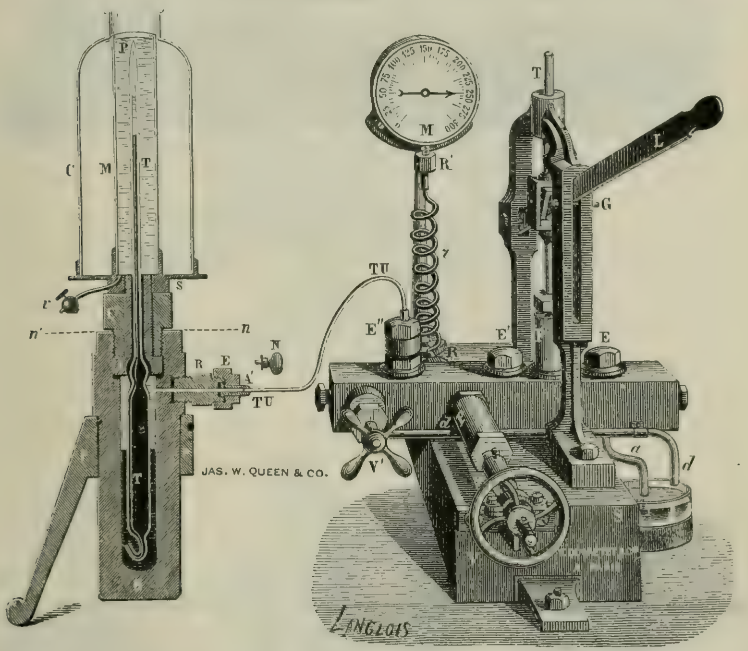
The instruments made by this house are too well known to require specification here. All the apparatus necessary for electrical measurements, Thomson reflecting galvanometer, Wheatstone bridges, Clarke's standard cells, condensers, electrometers, keys, etc., all accurate and well made, were exhibited.

C. J. Simmons also showed some good work in galvanometers, resistance coils and a standard ohm.

The general exhibit of Jas. W. Queen & Co. was of great variety and excellence, and the following list contains only a few of the more novel instruments, and those that deserve a special mention.

CAILLETET'S APPARATUS FOR THE LIQUEFACTION OF GASES.

With this apparatus all the gases may be liquefied, and it is so contrived that all the phases of liquefaction and the curious physical

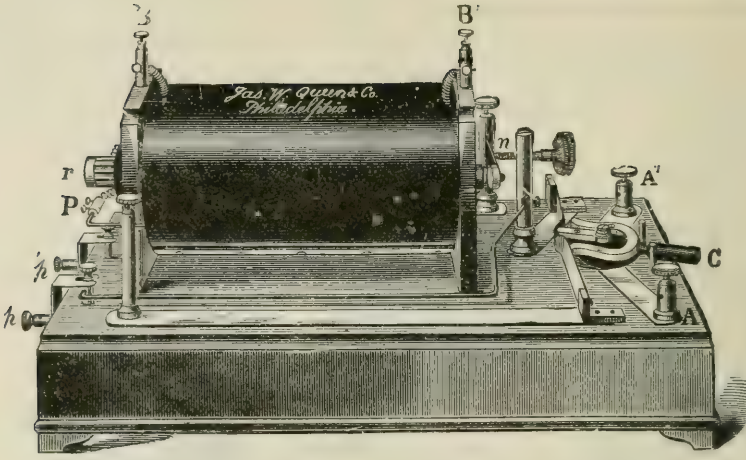


Cailletet's Apparatus for the Liquefaction of Gases.

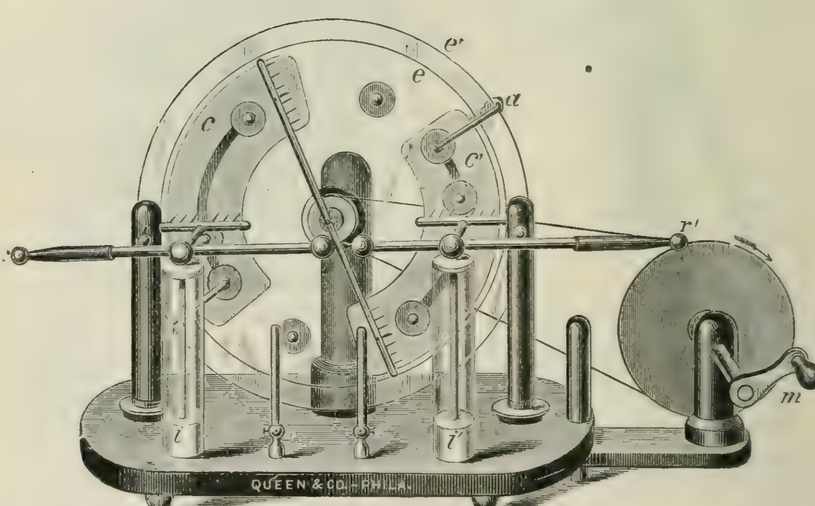
changes that take place at the critical point, may be watched without danger. With the pump a pressure of upwards of 300 atmospheres may be produced, and the gauge gives its indications in atmospheres.

RUHMKORFF COILS.

There were ten different sizes of these instruments shown, varying in length of spark from the one-eighth of an inch to six

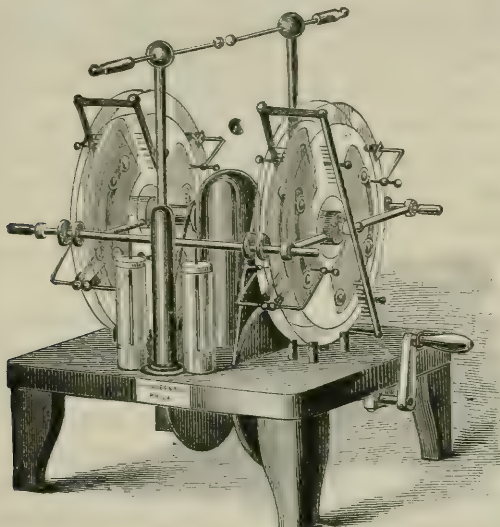


Dissected Ruhmkorff Coil, Bertin Commutator.



Toepler-Holtz Electrical Machine.

inches. Two of the larger of these were of special educational value on account of their structure, as they could easily be dissected. Such a form is more valuable than the one commonly sold for purposes of demonstration. The cut represents one of these, which is provided with the Bertin commutator *C*, which enables the operator to be certain of the direction of the current.



Queen's 4-Plate Toepler-Holtz Electrical Machine.

TOEPLER–HOLTZ ELECTRICAL MACHINES.

The Ramsden frictional machine was quite displaced by the invention of the Holtz machine, as the latter is much more efficient, and vastly more compact. But these machines required charging with a catskin or rubber disc, and would not always work. The self-charging machine called the Toepler-Holtz, leaves but little to be desired in that kind of a machine. There were exhibited, both foreign and home-made machines—all of them efficient.

One of these had a revolving plate ten and one-half inches in diameter, and would give a five-inch spark, while the larger plates give a longer and denser spark.

The cut shows one of the American forms of the Toepler-Holtz machines by Queen, finely finished in mahogany and nickel plated. It has an attachment for medical application, and its current may be taken either alternate or direct. These machines are also made

with double plates having the same diameter, an arrangement which increases their efficiency. By rotating one of the plates of such a machine, the other may be driven as a motor—a most interesting experiment.

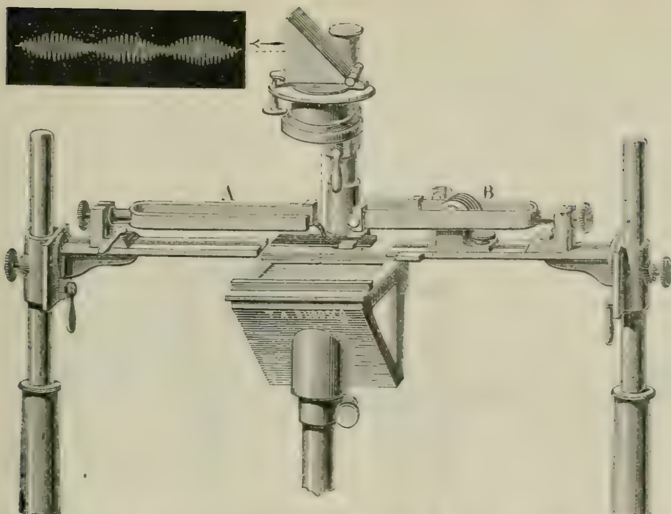
APPARATUS FROM TH. & A. DUBOSCQ, PARIS, EXHIBITED BY JAMES W. QUEEN & CO.

These makers exhibited some very complete optical apparatus for projection on the screen, and for general class and lecture use. Among these was the well known Foucault regulator (see illustration), also a hand electric lamp of a new design, devised by MM. Boudreaux and Th. & A. Duboscq, used at the Polytechnic School of the Sorbonne. They also exhibited a "lanterne photogenique," which is arranged for use with electric light. This is a very fine instrument with two apertures, so that two projections may be thrown on two screens simultaneously.

For use with this was also exhibited a new vertical projection apparatus, perfected by Th. & A. Duboscq, for the projection of two transparent bodies, solid or liquid. This apparatus is furnished with a large condenser of rectangular form, which makes it possible to obtain a very large field, which is an indispensable condition for the inscriptions in the projection of vibratory movements.

There is also in connection with this a very interesting apparatus devised by A. Duboscq, a universal support or electro-diapason, intended to inscribe and show in projection, the vibratory movements. This support on which the diapasons are placed, furnished with stylus and blackened glass, allows of the demonstration in projection of the inscription of intervals; of inscriptions of two vibratory movements, parallel or perpendicular; beats, and the inscription in projection of the optical figures of Lissajous and the experiments of Melde. For the projection of the inscription of sound intervals, with this very interesting apparatus, the two diapasons are placed, one on each support and each furnished with a stylus. The diapasons which have been placed opposite to each others' parallel axes are made to vibrate electrically, the styluses are side by side, and turn in the same way.

There are many other interesting accessories for use with this lantern in connection with electricity: the apparatus of M. Bertin for the electro-magnetic rotation of liquids in hollow magnets, as



Projection of Lissajous's figures by means of Vertical Lantern.

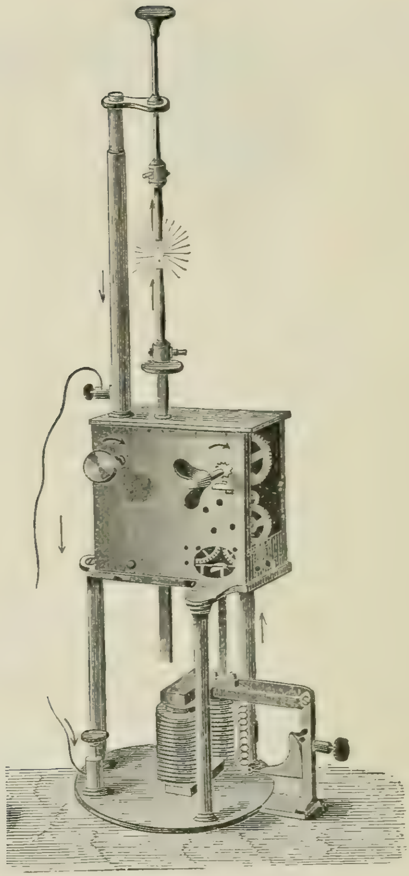
well as the apparatus for the experiments of Arago on the magnetism of rotation. Also a movable arch with support and a series of discs, black and colored, to show the persistance of impressions on the retina, contrast, the admixture of colors, and the complementary colors, with Newton's discs, etc., and the apparatus after Mayer, for showing the experiments of Oersted to demonstrate the lines of currents upon the magnetic needle.

These makers also exhibited a collection of concave and convex lenses upon stands for use with the lantern for projection with electric light; prisms, of solid glass and hollow, containing bi-sulphide of carbon, etc.

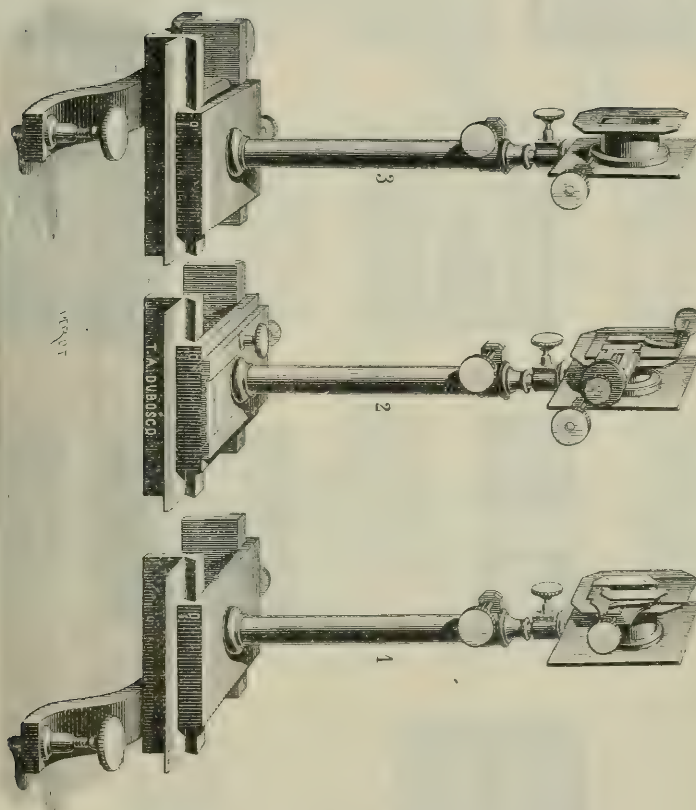
Also a new form of Babinet's goniometer, for student's use. A Norremburg apparatus for the study of polarized light, and a very beautiful spectrometer-goniometer, and a collection of photometers of various kinds, Bougeur, Bunsen and Foucault, etc.

They also exhibited a large diffraction banc. This was a very long and fine one divided into millimetres, and supplied with a very complete set of lenses, slides, prisms, etc., for showing interference, etc., as shown in the figures.

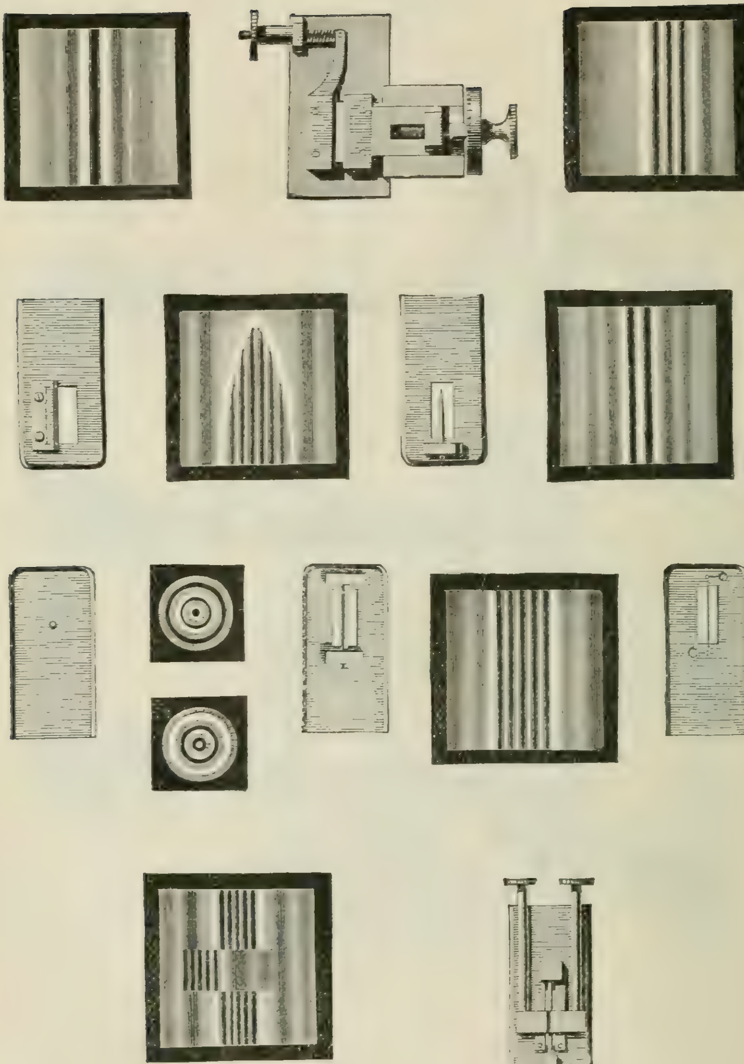
Although few of these instruments are intended for exact measurements, they were of great interest to teachers and lecturers on account of their adaptability for use before an audience, and



Foucault Regulator.

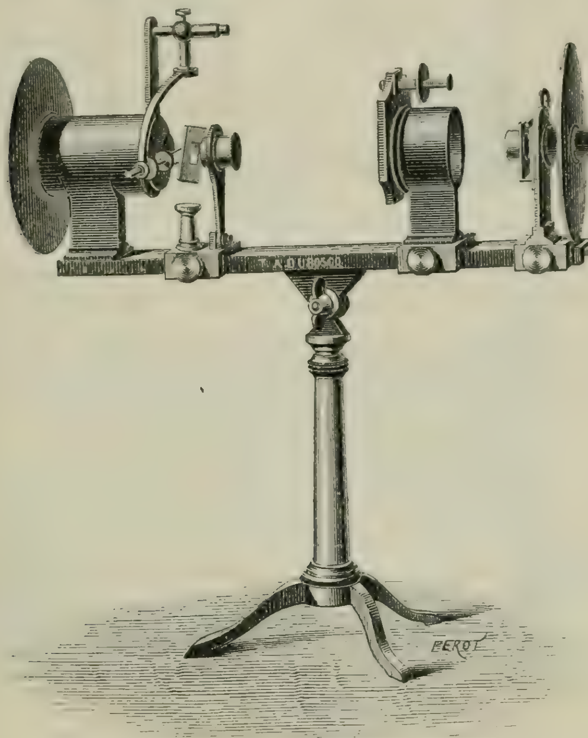


Diffraction Banc.



Interference Phenomena shown by the Diffraction Banc.

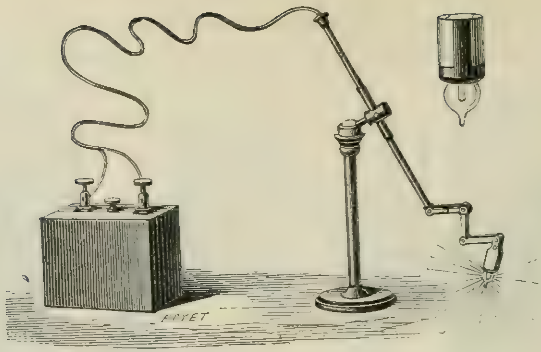
because of the skill which has been used to render them useful for exhibition by means of electric light which is now so much used for scientific work.



Apparatus for the Projection of Circular Polarization in Crystals.

In the collection of Th. and A. Duboscq was also exhibited a very fine apparatus for the projection of all the phenomena of double refraction, rectilinear, circular, elliptic, chromatic and rotary polarization. The apparatus was finely finished in brass, with movable lens and crystal holders, etc., as shown in the figure, with Nicol polarizer and analyser, Delezenne polarizer, glass pile, black glass plates, tourmaline, quartz parallel, quartz perpendicular, one-quarter wave micas, direct-vision prism, compensator and soleil biquartz, rectilinear aperture, microscope, etc., the whole capable of being used with any lantern or *porte lumière*.

L. Aboillard exhibited a fine collection of incandescent lamps

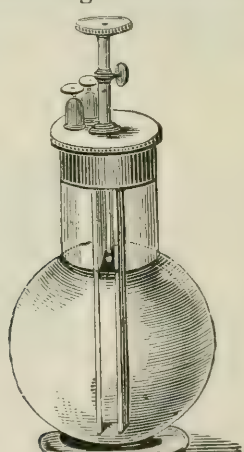


Aboillard's Articulated Electric Lamp Support for Microscopic Use.

from two to 100 volts, various styles of ladies' hair ornaments, butterflies, scarf pins, etc., with miniature lamps mounted in the centre, small pocket accumulators, articulated supports for lamps for microscopic use, etc.

GALVANIC BATTERIES.

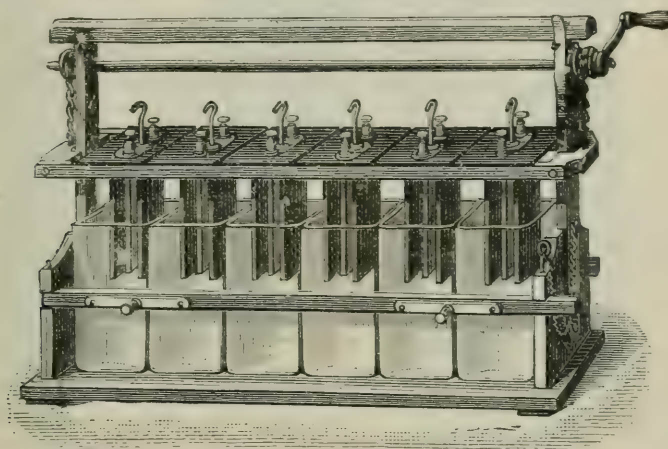
Galvanic batteries are yet the simplest and most convenient means for obtaining an electric current for most purposes not requiring great strength or constancy; and the variety of batteries adapted to different purposes is very great. In the report upon batteries will be found some data for judgment as to their adaptation to various uses. But there are many good batteries which were not examined, and among them are such as the Bunsen, the



Grenet Bichromate Cell.

Grenet and the Grove. Of these, the Grenet, or as it is most generally called the bichromate cell, is one of the best. When freshly set up its electro-motive force is just about two volts, and its internal resistance low. Such a one as is represented in the cut, holding out two litres of liquid will rarely measure over a quarter of an ohm.

But it is necessary to lift the zincs out of the solution when not in electrical action, as otherwise chemical action goes on and the zinc is dissolved. When several of these zincs are used together, it is exceedingly convenient to have all the zincs lifted out of their



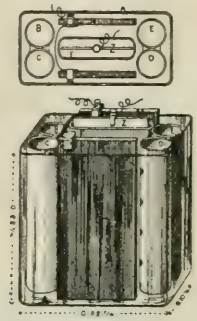
Queen's New Plunger Battery.

solutions at the same time, and Queen & Co. showed a battery of six such cells having a wheel and rachet for lifting out the elements from the liquid when not in use. Such a battery of cells has an electro-motive force of twelve volts, and will yield a current of about ten ampères on short circuit.

Such a battery will suffice for most illustrative and teaching purposes, but if incandescent lighting with it is desired, it will need a ten or eleven volt lamp, which will give four or five candle-power.

What is known as a Chloris Baudet battery or unpolarizable cell, proved upon test to be a first-class battery cell giving an electro-motive force of 1·87 volts, and with low internal resistance and a remarkable degree of constancy when compared with most other cells. This battery is a two-fluid battery, with the zinc in a

solution of an hydrogen-potassium sulphate in an ample porous jar and plates of carbon in the outer jar, which contains a saturated solution of bichromate of potassium and sulphuric acid as is usual in the Grenet cell. If the outer jar be made large enough to permit holding two small porous jars, one to contain strong sulphuric

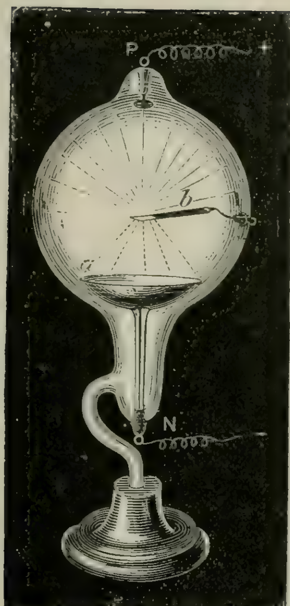


Chloris Baudet Battery.

acid, and the other crystals of bichromate of potassium, these will diffuse themselves and maintain the strength of the solution. Thus the battery may give a strong constant current for several days.

GEISSLER & CROOKES TUBES.

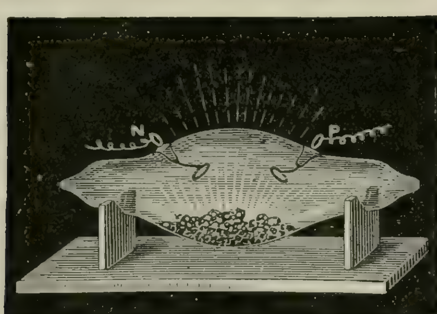
Queen & Co. exhibited over a hundred varieties of these most interesting and instructive tubes, some of them of great size and beauty. They had provided a darkened room, where they could be seen to advantage in the day-time. These tubes are now so well known that no description of them is needed here, but the committee would remark that aside from the great beauty of some of these Crookes tubes when lighted up by molecular bombardment, the tubes may serve for demonstration in every department of physics. The first laws of motion in mechanics, the development of heat by impact, the development of radiant energy by impact, the production of visible motion and of sound by molecular impact, the electrical phenomena of parallel electrical currents, the effect of magnets upon electrical currents, phosphoresence, fluorescence, etc., etc., so that an ingenious teacher might demonstrate nearly every principle in physics with an appropriate set of Geissler & Crookes tubes. The cuts represent some of the most remarkable of these tubes for the development of motion, incandescence, phosphorescence and the shadow.



JAS. W. QUEEN & CO.

Crookes' Tube. Showing the Molecules thrown to a Focus producing Heat in a piece of Platinum Foil.

Crookes' Tube. Containing a Crystal of Iceland Spar.



JAS. W. QUEEN & CO.

Ruby Tube. Containing Shells and Minerals of various kinds.

GENERAL PHYSICAL APPARATUS, NOT ELECTRICAL, EXHIBITED BY JAMES W. QUEEN & CO.

A few of these possessing more than ordinary interest, it is thought best to mention here; not with the idea of making a report on them, but because they were exhibited, attracted the attention of many visitors, and were worthy of attention.

A collection of sections of crystals, quartz lenses and prisms and glass crystal models, by Drs. Steeg and Reuter.

One set in a mahogany case contains 178 sections of crystals and preparations. A quartz lens, 75 mm. in diameter and 1,500 mm. radius. Also a cube of uranium, dydimium and sappharine glass and fluor spar, in a case.

A large exhibit of glass crystal models, beautifully made and arranged, showing accurately the axis of the crystals. There were fifty of these models.

Cathetometers of several sizes and forms. One was particularly well adapted to laboratory work, both physical and chemical. It was one and one-quarter metres high, and is so arranged that it may be used either vertically or horizontally. One of these when tested was found to be as accurate and as convenient to use as some costing three or four times as much.

There were models of telescopes, the galilean, the astronomical and the terrestrial, with the direction of the rays indicated by colored threads which are useful helps to beginners in such studies. Also a similar model of a compound microscope.

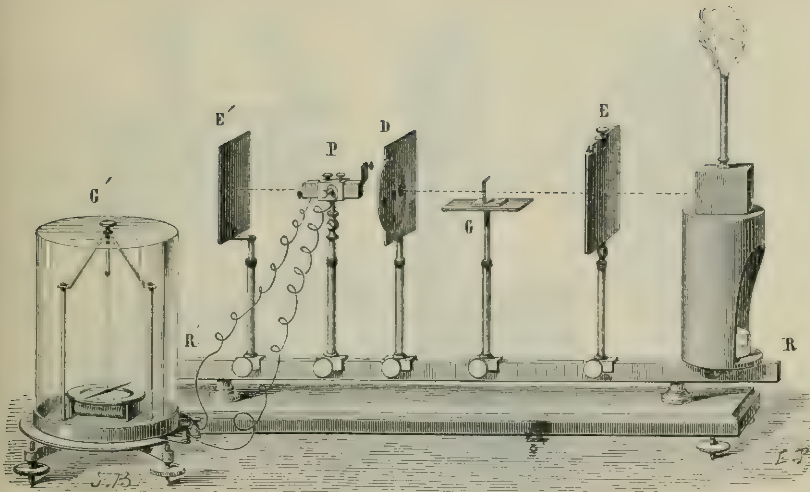
A number of rock salt prisms and lenses, one of the latter being eighty-five mm. in diameter, and thirty collections of gelatine films for selective absorption of colors; the coloring was said to be with chemically pure substances. In each of these sets there were thirty films forming a very convenient and tolerably complete collection.

MELLONI'S APPARATUS.

A finely constructed piece of apparatus for delicate experiments in heat, with between thirty and forty accessories, was shown. It was manufactured by Carpentier, of Paris, and was contained in a very neat and compact case for safe keeping and transportation.

OPTICAL BANC.

There were two of these pieces of optical apparatus with numerous accessories. One of them made of mahogany two metres long



Melloni Apparatus.

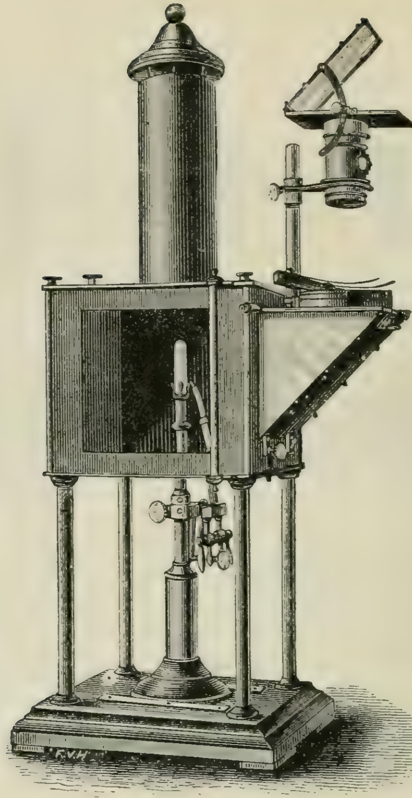
and a veneered maple scale graduated to five centimetres. The other one a simple wooden bench one metre long with eight slides, sufficiently good and accurate for most educational purposes.

There was also displayed a fine collection of microscopic apparatus of the finest workmanship, the collection of objects for polariscopic study was very extensive, and many of the objects themselves very beautiful and deserving of mention.

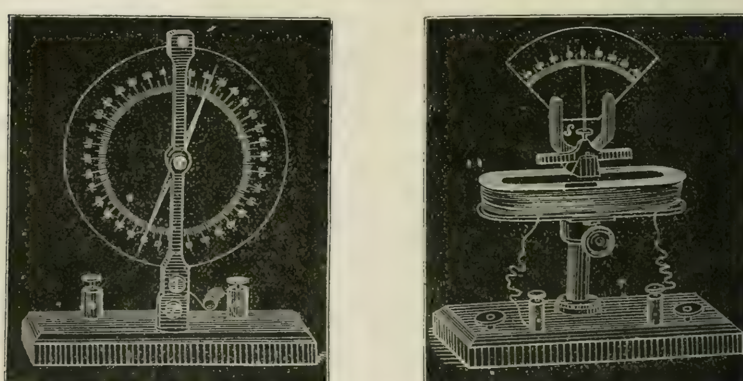
APPARATUS FOR PROJECTION.

A lantern adapted for the projection of all sorts of physical phenomena, as well as the simple projection of transparent photographs was shown. The rivalry among different makers of such pieces has served to develop during the past ten years this very useful adjunct to an educational institution, until almost any phenomenon may be shown upon the screen; and what is really needed is a lantern which can be easily and quickly changed and adapted to different classes of work. Considerable experience has led to the conclusion that such a lantern as was exhibited by Queen & Co. is adapted to as great a variety of work and is manipulated as easily as any one with which the committee is acquainted.

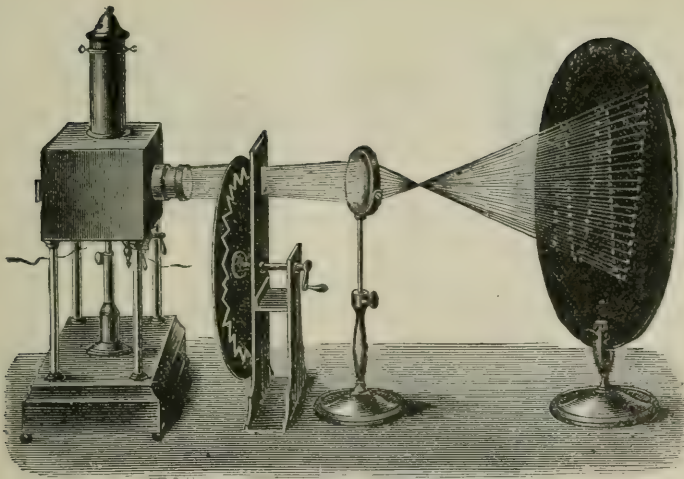
The application of minute incandescent lamps for the illumination of the microscope, has recently attracted considerable



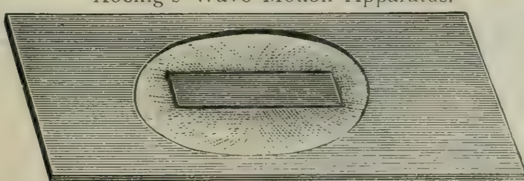
Projector, with Vertical Attachment for Chemical and Physical Experiments.



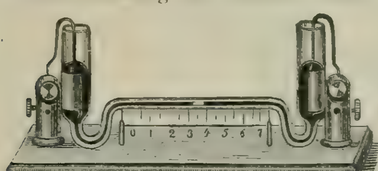
Galvanometers for Projection.



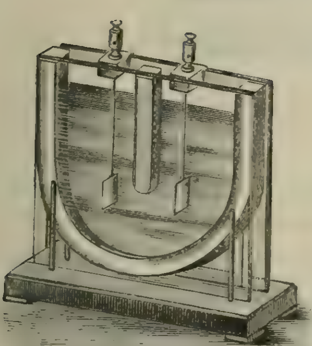
Koenig's Wave Motion Apparatus.



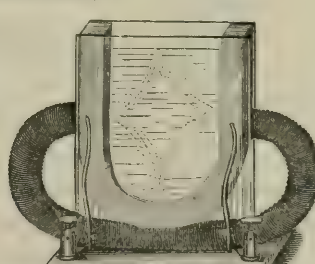
Slide Showing the Lines of Force.



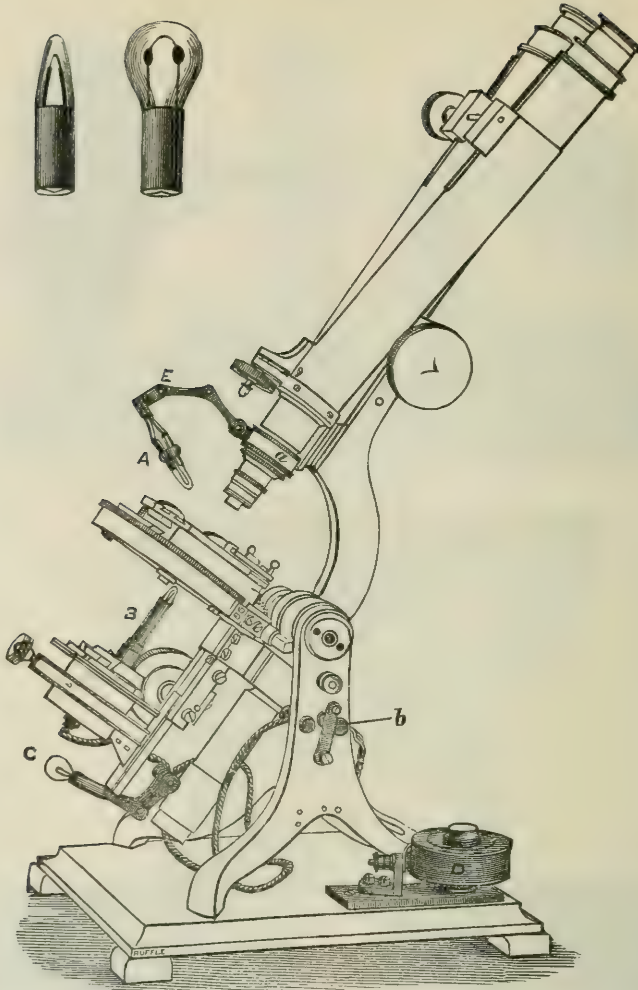
Weinhold's Capillary Galvanoscope.



Voltameter for Projection.



Electro-Magnet for showing lines of Force by means of Iron Filings in a Tank of Glycerine.



Microscope, Illuminated by Incandescent Lamps, showing (for convenience of illustration) several different Forms of Mountings at once.

attention. Messrs. Queen & Co. exhibited five microscopes, binocular and monocular, with various forms of mounting.

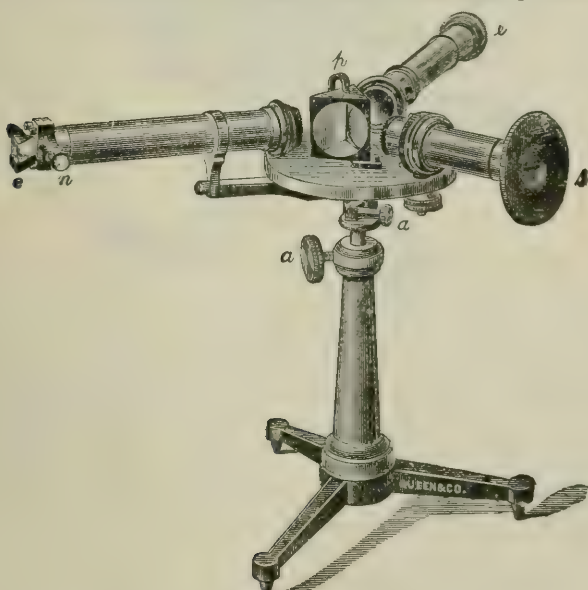
One of these is a mounting which fits in the holder of the mirror (the latter being removable) below the sub-stage condenser; another is a separate stand, so arranged with universal movements, that opaque and transparent objects may be lighted with equal

ease. A modification of the latter form fits into the stage forceps hole in the stage.

A form sometimes preferred is where the lamp is mounted to fit in the sub-stage, immediately below the object.

A resistance coil, specially arranged for use with these lamps, was also exhibited. The current is obtained from bichromate batteries, and secondary batteries are also admirably adapted where they can conveniently be charged. A small dynamo machine has very recently been applied to light the lamps direct.

Queen & Co. also exhibited a new spectroscope and goniometer combined. This instrument was specially worthy of attention on account of its excellence of design and workmanship, and reason-

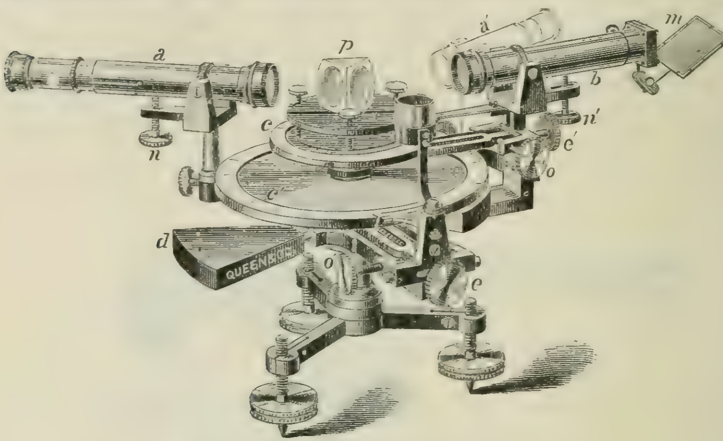


Queen's new Laboratory Spectroscope.

able price. It is supplied with two graduated circles of silver, respectively ninety-five and 105 mm. in diameter. It has a micrometer and vernier, each reading to five minutes. The telescopes are properly balanced to give ease of motion and prevent wear, and are provided with both vertical and horizontal adjustments, while an extra arm permits the telescope to be reversed for use with a grating. The prism stage rotates independent of the circles below, and can be adjusted by means of levelling screws to any

position desirable for either grating or prism. A small heliostat on an universal joint is attached to the slit, thus avoiding the necessity of an extra mirror.

They also exhibited a new laboratory spectroscope for teacher's and student's use, furnished with a flint glass prism *p*, thirty-three mm. high, improved slit, with micrometer screw *n*, adjustable telescope *l*, by means of clamping screw *a*, the telescope has 7 mm. aperature, 147 mm. focus. The prism and telescopes are



Queen's Spectrometer for Laboratory.

mounted on a finely finished brass table, supported on a neat tripod stand, the table is adjusted vertically, and can be fixed by a set screw at the side, complete with comparison prism and photographed scale for measurement of spectra. This spectroscope supplies a long-felt want, and will be of great service for student's use to save larger and finer instruments in the laboratories of universities.

EDUCATIONAL EXHIBIT OF DR. A. E. FOOTE.

This exhibit consisted of a collection of crystals and massive specimens of minerals. The specimens were of the finest sort, and many of them unique. There were collections suitable for instruction in mineralogy and geology, with huge specimens of crystalline masses of quartz, agates, flour spar, amazon stone, beryl, etc.

Henry Whitall exhibited his well known heliotellus and planisphere both efficient as astronomical illustrations, and much used during the past fifteen or twenty years.

Respectfully submitted, A. E. DOLBEAR,
Chairman Section XXIX.

SECTION XIII. APPARATUS FOR HIGH ELECTRO-MOTIVE FORCE. CLASS 2. ELECTRO-STATIC INDUCTION MACHINES, INDUCTION COILS, ETC.

The Committee of the Board of Examiners, to whom was deputed the duty of noting the exhibits in the above class, beg leave to report as follows:

None of the exhibits in this class were entered for competitive examination, they were mainly educational instruments, contained in the exhibit of Messrs. James W. Queen & Co., philosophical instrument makers, of Philadelphia. The committee has thought it advisable, however, to mention briefly some interesting novelties which were found in other exhibits, and which have not yet received public notice

Commencing with the exhibit of Messrs. Queen & Co., the following apparatus may be noted.

(A.) TOEPLER–HOLTZ MACHINES.

There were quite a number of these instruments of different sizes, having one, two and four plates each, the revolving plates varying in size from twenty-six centimetres to ninety centimetres, and having simple self-charging appliances. These instruments worked satisfactorily, yielding a torrent of electric flashes with an expenditure of very little labor. They were conspicuous for their fine finish, nice adjustment, and perfect workmanship. Their immense superiority over the old frictional electrical machines, or the earlier forms of the Holtz machine, has caused them to supplant these entirely. It may be said that they mark an era of progress in the improvement of electro-static induction machines as remarkable in this field of research as has been achieved by the dynamo-electric machine in its sphere.

While the electro-static induction machine cannot compare with the induction coil in its perfect reliability of action in all weather and under all conditions, the improvements noted in its construction have materially enlarged its usefulness in various directions.

(B.) INDUCTION COILS.

A number of coils, both of Messrs. Queen & Co.'s manufacture and imported from M. Ruhmkorff, were shown, varying from miniature size, giving sparks of thirty millimetres, up to instruments giving sparks thirty centimetres long. Some of these machines were provided with the Deprez automatic break, and others with the Foucault interrupter. Some were wound in sections and others were so constructed that they might be taken apart without injury, and the connections exposed to view for purposes of study.

All of these instruments were finished in the best manner, and exhibited a thoroughness of workmanship as well as ingenuity of arrangement, which is highly creditable to the manufacturers.

(C.) GEISSLER TUBES.

These are glass tubes of more or less intricate construction, (sealed at each end and having terminal wires of platinum) from which the air, or other gas, has been exhausted until the pressure does not exceed half a millimetre of mercury. They are designed to exhibit the well known and beautiful phenomena of electric discharge in rarefied gases. In addition to the ordinary forms of Geissler tubes, there were several novel ones of interest. The fluorescent and phosphorescent tubes exhibited were remarkable for their brilliancy. In addition to the above, there were a number of Plucker's spectrum tubes, containing traces of various gases, elements and compounds, yielding brilliant spectra when illuminated by the discharge from an induction coil or Holtz machine, and examined by means of a spectroscope.

The so-called "end on" spectrum tubes are especially valuable in spectroscopic research; from their construction it is possible to obtain the full value of the illumination through the *whole length of the tube* instead of transversely, thus giving vastly more light than the ordinary spectrum tubes, and yielding more brilliant lines.

(D.) CROOKES' TUBES.

It is probable that nothing in the exhibition excited more interest than the exhibit of the magnificent tubes designed by Professor Crookes, to illustrate the properties of so-called "radiant matter." Many of these tubes were four times the size of those used by Professor Crookes in his remarkable address before the British Association, in 1878.

They differ from ordinary Geissler tubes in the more complete exhaustion of the air (not over $\frac{1}{1,000,000}$ of an atmosphere remaining) and from the fact that the ordinary effects of Geissler tubes are absent, while a whole new series of remarkable phenomena appear. It is upon the evidence afforded by the peculiar behavior of the radiant matter in these tubes, when under electrical excitement, that Professor Crookes rests his claim to have revealed matter in a state as far removed from gas as gas is from liquid, or liquid from solid, and he called this supposed new condition the "Fourth State of Matter."

The exhibit comprised all of the forms of apparatus first used by Professor Crookes, as well as some tubes of quite recent device. Messrs. Queen & Co. fitted up a small apartment where these tubes were exhibited to a few people each evening. This firm deserves creditable mention for its enterprise in procuring so large and valuable an exhibit of fine apparatus of foreign and domestic manufacture.

The remarkable discoveries of Professor Crookes have been so fully described in the scientific journals that a detailed notice has not been deemed necessary in this report.

EDISON'S TRI-POLAR INCANDESCENT LAMP.

Apropos to this description of Professor Crookes' radiant matter apparatus may be mentioned briefly a very curious and interesting incandescent lamp in the private exhibit of Mr. Edison, showing phenomena apparently analogous to those of Professor Crookes' radiant matter tubes.

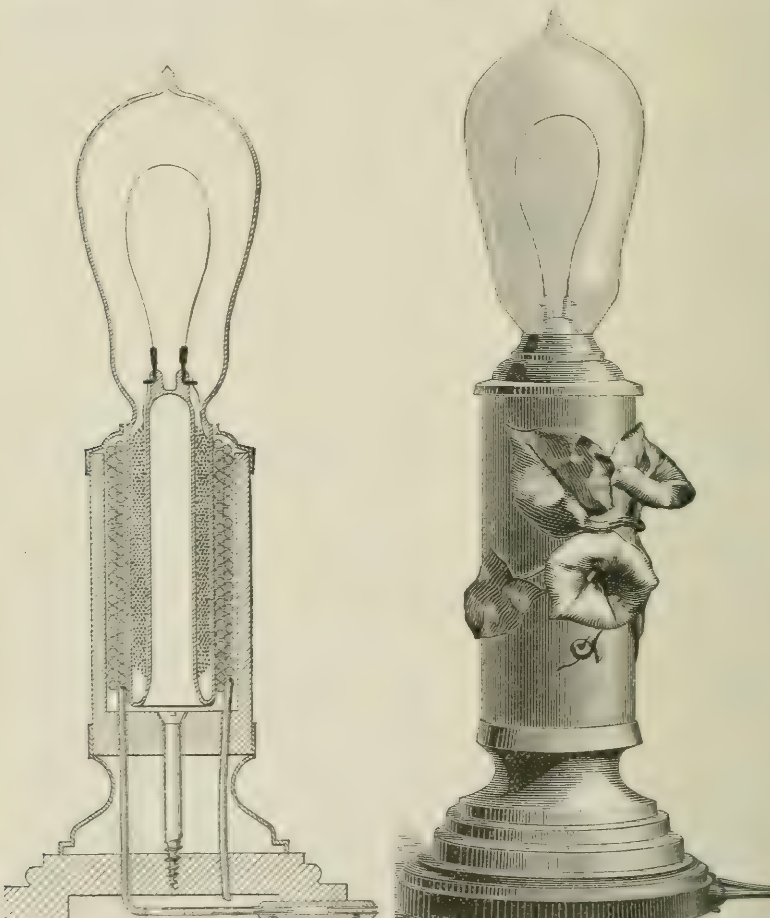
In this lamp a third terminal is inserted, to which is attached a thin strip of platinum foil, which projects upwards to within about two centimetres of the centre of the carbon loop. When the loop is rendered incandescent by an electric current from a dynamo-machine and a connection is made (with a galvanometer in circuit) from the positive pole of the lamp to this third terminal, it is found that a strong current of electricity flows through the galvanometer. This anomalous action has been variously explained, but several experiments have been made with this lamp which indicate that the phenomenon is similar to that discovered by Professor Crookes. For example, it is found that when the platinum pole is enclosed in a glass tube sealed into the bulb in such a position that the

platinum foil is in a direct line with the carbon, the phenomenon appears as before, but when the tube is bent at right angles, no such effect takes place.

Several other interesting experiments with this lamp were described, but not shown, and the effects observed are worthy of more careful study than the committee was able to give at the time.

DIEHL'S ELECTRIC–INDUCTION INCANDESCENT LAMP.

In the exhibit of the Singer Sewing Machine Company, the committee found several ingenious forms of incandescent lamps in



Diehl's Electric Induction Incandescent Lamps.

which no terminal wires penetrate the glass, the whole action depending upon induction through the glass.

These lamps were devised by Mr. Philip Diehl, of Elizabethport, N. J., and require an intermittent current to develop the inductive action; the current from the dynamo does not enter the lamp, but passes into a coil of wire which surrounds a glass tube, forming the base of the bulb. Inside the tube is a second coil, whose terminals are connected with the carbon filament, and when the intermittent current is passed through the outer coil, a secondary current is induced in the inner coil, which heats up the carbon to the point of incandescence.

The inventor stated that the best form of lamp which he had been able to produce on the induction principle, has an interior or secondary coil of only four layers of No. 30 B. & S. gauge, uncovered copper wire. The first layer is wound directly on the inwardly reaching tube of the glass globe, the other layers are insulated from each other by thin sheets of mica, the wire being wound so that there is no point of contact. Naked copper wire is used in preference to insulated wire coil to facilitate the subsequent evacuation of the bulb, as any form of insulating material tends to retard the perfect exhaustion. In order to increase the inductive action, bundles of iron wire are inserted in the centre of the tube, around which the secondary coil is wound.

The weight of copper wire used for the interior coil is one-third of an ounce.

The exterior coil consists of but two layers of naked copper wire, No. 16 B. & S. gauge. These layers are insulated from each other with asbestos paper, the weight of wire being three and one-half ounces.

The exhibitor claimed that the largest lamp shown would give a light of about forty candles, and stated that he had run five of those lamps with an expenditure of one horse-power, and that he was confident that still better results could be obtained when the true proportions of the coils are found by further experiments.

Another style of incandescent lamp was shown, having interior and exterior condensers, intended to be used with currents of very high electro-motive force, as in the Geissler, or Crookes tubes, except that there are no terminal wires liable to become heated, and so destroy the seal. The condensers form a sort of accumu-

lator, so that when the current of electricity is momentarily interrupted, the steadiness of the light will not be affected.

After some difficulty, owing to the absence of the inventor and the want of a suitable dynamo for this purpose, the committee succeeded in operating two of the lamps, by introducing a circuit breaker, but it was not possible to make any tests, either of the candle-power of the light or the power consumed, but the committee is able to state that the carbon filaments glowed with a steady and fairly brilliant light; and while no opinion is expressed as to the practicability of this form of lamp, it was thought that it possessed sufficient novelty and interest to warrant a brief notice in this report.

If there are any other exhibits which the committee has omitted to mention, it must be attributed to the neglect of the exhibitors to notify the Chairman of the Board of Examiners of the objects which they desired to have reported upon, and to the want, during the earlier part of the Exhibition, of an official catalogue.

All of which is respectfully submitted by

JOHN B. DE MOTTE, *Chairman*,
A. E. OUTERBRIDGE, JR., *Secretary*.
Committee on Section XIII, Class 2.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XXVI.

(SECTION VII, OF THE CATALOGUE.)

"Applications of Electricity to Artistic Effects and Art Productions," with which is Incorporated Section XXV, "Applications of Electricity to Musical Apparatus."

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, MAY, 1886.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1886.

EDITING COMMITTEE.

PERSIFOR FRAZER, *Chairman*,
CHARLES BULLOCK,
THEO. D. RAND,
COLEMAN SELLERS,
WILLIAM H. WAHL.

1884–INTERNATIONAL ELECTRICAL EXHIBITION–1884

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXVI.—APPLICATIONS OF ELECTRICITY TO ARTISTIC EFFECTS AND ART PRODUCTIONS.

To the Board of Managers of the FRANKLIN INSTITUTE:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XXVI, on "Applications of Electricity to Artistic Effects and Art Productions."

Respectfully,

M. B. SNYDER,

Chairman Board of Examiners.

PHILADELPHIA, January, 1886.

PROF. M. B. SNYDER,

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—The Examiners in Section XXVI, respectfully present the following report.

FRED. GRAFF,

Chairman Section XXVI.

PHILADELPHIA, January, 1886.

REPORT:

THE APPLICATIONS OF ELECTRICITY TO ARTISTIC EFFECTS AND ART PRODUCTIONS.

The Committee at its several meetings very quickly came to the conclusion that, owing to exhaustive sub-division of the labors of the Board of Examiners, very little original sphere of action remained for its consideration. Two subjects, and only two, appeared to call for report under its functions. (1.) The influence of electric lighting upon decorative taste. (2.) The application of electric lighting to photography.

I.

Whoever visited the exhibition at night, needs no reminder of the growing applications of electricity to the production of artistic effects. By its aid, the crude building, hurriedly erected without attempt at finish for a temporary purpose, was transformed into a temple of light, which at the first glimpse evoked expressions of delight from every beholder.

The exhibits of Edison and Weston were especially worthy of remark in foreshadowing the future general use of electricity in domestic decoration. Revolving stands laden with flowers, whose beautiful bright columns were disclosed by the electric lamps distributed amid their green foliage; purling fountains subsequently illuminated with various hues; glowing bouquets, all apparently usual features of a modern drawing room, gave a foretaste of the æsthetic furnishing of the future. It is evident that the general introduction of the electric light must have a most decided effect in the modification of everything that appeals to our taste. House decorations, dress materials, must all be fabricated with the condition of producing maximum pleasing effect under powerful and searching electrical illumination. The vista of possibilities of discussion opened from this point of view is illimitable, and the section has concluded—wisely it is hoped—to refrain from entering it. A probable reflex result may, however, be mentioned.

Physicians agree that we suffer in our homes from want of sunlight. We furnish, dress, and live for gaslight. When our surrounding shall have been accommodated to the brilliant illuminant of the future, we need no longer shut out the bright light of day,

under whose health-giving sheen, dull eyes and waxen cheeks will brighten and bloom.

II.

Mr. W. Curtis Taylor, of Philadelphia, established an electrically lighted *atelier* in the Exhibition Building, and thus gave opportunity to thousands of practically witnessing the photography by electric light.

Owing to the circumstances of the case, he was necessarily cramped in room, yet notwithstanding this drawback, he was very successful in results. His method is fully described in the report herewith appended. Mr. Kurtz, of New York, exhibited some remarkably beautiful photographs taken by electric light. The Chairman and Secretary of the Section visited his studio in New York, and through his courtesy and that of his assistant, Dr. Ehrmann, were placed in full possession of the details of his method of procedure.

The apparatus employed by Mr. Kurtz, as will be seen by the description and wood-cuts given in Appendix B, is much more elaborate than that used by Mr. Taylor, requiring a skilful and artistic operator to manipulate the numerous lights and the movable posing platform.

Mr. Taylor's whole arrangement is exceedingly simple, can readily be erected and put in use in the usual photographic gallery. Its manipulation is comparatively easy, the cost of getting up the apparatus is low, compared with that as employed by Mr. Kurtz. It must, however, be conceded that the latter gentlemen has produced with his arrangement wonderfully artistic and perfect work, quite as good as many made by daylight.

Mr. C. H. James, of Philadelphia, exhibited some striking views of parts of the "Caverns of Luray," taken by electric arc lights, in 1882. The details of the method of doing this difficult work are contained in Appendix C.

FRED. GRAFF, *Chairman.*
O. E. MICHAELIS, *Secretary Section XXVI.*

APPENDIX A.

1328 Chestnut Street, Philadelphia.

FRED'K GRAFF, ESQ., *Chairman, etc., Section XXVI, International Exhibition* FRANKLIN INSTITUTE.

DEAR SIR:—As an accompaniment to the collection of photographs, which I shall have the pleasure of presenting to the FRANKLIN INSTITUTE, I beg to offer the following description of our studio in the Exhibition Building, where the negatives were made.

Since making the experimental photographs, in the hall of the FRANKLIN INSTITUTE, in 1877 (believed to be the first made by electric light in America), I had not used artificial light for making negatives until my present arrangement was put into operation at your Exhibition.

Methods elsewhere adopted for photographing from life by electric light may be classed under two principal heads: (1.) The use of one or two powerful lights in conjunction with condensing reflectors of moderate size, and (2) the use of a large number of moderate lights without condensation.

In the first, it is sought to avoid the hard effects by making either the lamps or the sitter change position constantly during the operation, in order to round off the shades and produce modulation of the features. The former is the method of Liebert in Paris and Van der Weyde in London. I am able to lend for your inspection photographs by Liebert, taken at the Paris Exhibition, in 1881; and you have, in your own Exhibition, specimens of the work of Van der Weyde. I think you will agree that in each of these is a too definite line of demarcation between the lights and shades.

Mr. Kurtz, of New York, makes his sitter and camera box revolve together under a fixed light. He also has specimens in your Exhibition. Being a skilful and pains-taking artist, Mr. Kurtz has produced excellent effects by this means, where the mere photographer would have made a miserable failure. As a strong objection, however, to his method, I submit that most sitters would find it very inconvenient to be swinging about; as at such a time they find it hard enough to keep tranquil even under the most favorable circumstances.

Mr. Mayall's light in London, is on the principle classed above as second. He uses a great number of Swan's incandescent lamps,

arranged in circles over and around the sitter, but so far as my latest information goes, no general diffusion or softening of the light is otherwise attempted. It cannot be agreeable to the eye. I have seen no specimens of his work.

It was my object, when preparing for the present Exhibition, to imitate as closely as possible the natural daylight effects of our permanent studios, the result of long and general experience of photographic needs. The problem, then, was to produce a flood of gentle, but sufficient, white light, to cover such an area at the top and one side as should throw over and around the subject, from this *one* source, a light of its own nature diffused and requiring no counter lights for its modification. This is precisely what we do in our skylights. To effect the same purpose at the Exhibition we placed two arc lights of 1,000 candles each near the central line of the studio, 4 feet apart, and about 8 feet 6 inches from the floor. The light nearly overhead to the sitter is covered with a porcelain globe; the other with a glass globe, ground on the lower

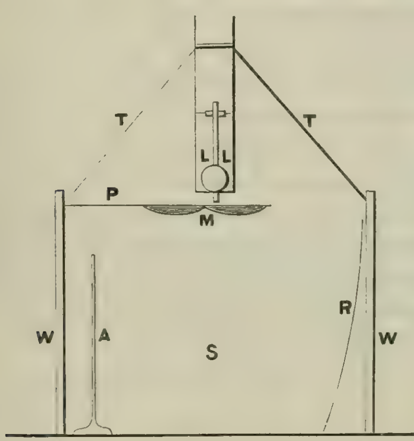


FIG. 1.—Section of Studio at International Exhibition of FRANKLIN INSTITUTE. Plan by W. Curtis Taylor. 1884.

W W.—Side walls of studio.

L L.—Arc lamps arranged parallel with sides of room.

T.—Tent.

P.—Tissue paper to diffuse light.

R.—White drapery, adjustable; for reflection.

A.—Dark screen, adjustable; for absorption of light.

S.—Usual position of head of sitter.

M.—White muslin, to subdue too intense light over sitter's head.

half and clear above. Covering these was a white muslin tent, the whole size of the apartment (which was 10 x 12 feet) and rising at the apex about 4 feet above the lamps. Spread on wires below the lamps was a sheet of silicated tissue paper, nearly the size of thetop of the room, and about eight feet above the floor. This served the double purpose of further diffusing the great body of light shed down from the lamps and the white tent, and of bringing the light nearer to the floor, thus increasing the angle of illumination. This paper stopped about 2 feet 6 inches short of that side of the room corresponding to the "side light" of an ordinary studio, in order to allow the unobstructed light to pass over it at that place. The free light from above here fell upon a white muslin reflector, hung on the wall, and reaching to the floor. The force of this reflector was varied by inclining it at a greater or less angle to the light rays. On the opposite side of the room a greater or less exposure of dark drapery determined the position and depth of shade required for artistic effect.

From what is here stated, it will be seen that the prominent and peculiar feature of this plan is the simplicity of its means for producing around the subject a great extent of diffused and non-brilliant light. The common remark of all who saw it for the first time was that it was "softer than daylight," yet it was sufficient to make a perfect dry plate negative in six to twelve seconds.

On this, the closing day of the Exhibition, I will add, as the result of our experience, that nothing was needed to make our experimental light right as to principle but more space in our studio. There is a certain atmospheric effect, hard to be described, which it is impossible to get in a little cooped room.

Respectfully submitted,

W. Curtis Taylor,

October 11, 1884.

APPENDIX B.

Mr. Kurtz endeavors to secure as thorough diffusion of the light as possible by multiplying the number of arc lamps, and providing each with globes of ground oropaline glass, or with lanterns of thin tissue paper. The lights may also be grouped in various ways relatively to each other. But not satisfied with this, Mr. Kurtz resorts to the expedient of placing both the sitter and the

camera on a platform pivoted on a centre pin, and of rotating the platform during the operation of photographing so as to vary the angle at which the light from each lamp strikes the sitter. In this way the light is made to strike each feature at every angle as it passes successively from a shady to a lighted position or vice-versa, and thus an artificial diffusion is obtained which produces superior blending effects in the lights and shadows of the picture.

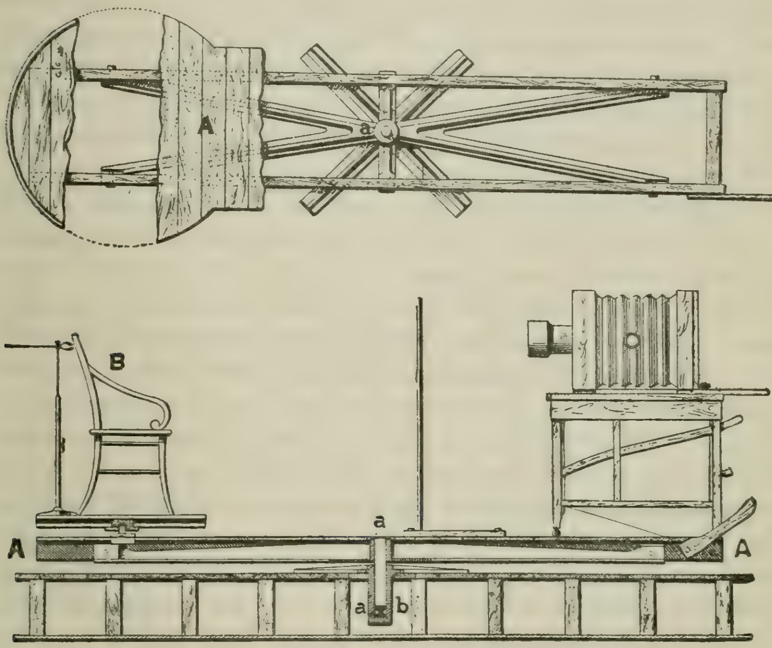


FIG. 2.—Plan and Section of Turn-table.

A.—Movable platform.
B.—Chair for sitter.
C.—Camera.
a b.—Pivot upon which the platform revolves.

The camera occupies one end and the sitter the other end of the platform, which is raised above the floor and turns on its centre on a steel pin which is received in a vertical bearing in the centre of the floor. The frame of the platform consists of two cross beams superposed at the centre, and supporting two parallel beams extending lengthwise and upon which the flooring is laid transversely.

This construction gives great solidity to the platform and diminishes the chances of vibration, whether lateral or longitudinal, by which the sitter and the camera might be disturbed relatively to each other, as the platform is rotated by the operator. This is important, for if the platform vibrated in this manner the image in the camera would be displaced to and fro to a slight extent, and the picture would be blurred and indistinct. A curved screen placed behind the sitter serves as a kind of concave reflector, which assists in diffusing the light from the lamps. The camera stand is supported on wheels, and it is movable on a small track (not shown in the engraving) from one side of the platform to the other in the arc of a circle of which the centre is exactly at the point occupied by the sitter. This innovation will greatly interest photographers, and it reflects credit on the ingenuity of Mr. Kurtz. The utility of this arrangement is very great. It is customary, at least in this country, to take several views of each sitter, in different presentations, such as full face, right side, left side, etc., and let the sitter select from the proofs of the negatives that which is the most suitable. In every case it is necessary to re-focus the camera with each change of position. But with this arrangement the camera remains in focus as it moves, and thus two or more positions may be photographed without trouble to the operator, who simply pushes the camera sidewise and exposes a fresh plate. The arrangement by which the operator is enabled to dispose the lamps at the convenient distance, and in the proper relation to the sitter, is most ingenious, and recalls the overhead railways found in machine shops where heavy pieces of machinery are to be moved from one machine to the other. The group is composed of six arc lights, which are suspended from a transverse frame extending horizontally from one side of the room to the other at a little distance below the ceiling, and which constitutes a travelling carriage, provided with wheels or rollers and moving on wooden rails extending from one end of the studio to the other on each side and supported by wooden brackets.

The transverse frame itself carries a smaller carriage which moves from one side of the room to the other, and supports the screen-holder, consisting of a horizontal frame which rotates on a vertical pin projecting down from the smaller carriage. To this frame, a flat screen is hung on couplings, so that it may be disposed

at any angle, from the vertical to the horizontal. The larger or main travelling carriage supports three of the six arc lamps, and the screen-holding frame supports the remaining three. It will be seen that in this way the lights are in reality divided into two groups which can be moved together or singly. Thus, when the transverse frame is moved, the whole system moves, but when the smaller carriage is moved, from side to side, only three lights are moved, thereby establishing a new relative position between the two groups, which may be varied still further by swinging the screen-holder which supports them. Not satisfied, however, with the facilities for varied diffusive effects which this arrangement affords, Mr. Kurtz has provided each lamp with its own small travelling carriage, so that the lights of each group may be moved from side to side as occasion requires.

Mr. Kurtz has adopted the electric lighting system of the Excelsior Electric Company of this city.

The time of exposure is not greatly in excess of that required under an ordinary skylight. A cabinet size head taken with a 3 B Dallmeyer lens, using a No. 2 stop and on a plate of average capacity (Mr. Kurtz's own manufacture in most cases) requires five to eight seconds, although the time has been reduced to three seconds under special circumstances. For measurement, a metronome is used.

In the basement of the premises connected with the main establishment, there is a branch for the photographing of technical and other inanimate objects; for the reproduction of maps, prints, drawings, etc.; silver printing and the making of process plates—all being done by the electric light. Here was recently accomplished the photographing of the electric spark of the telephone in the $\frac{1}{24,000}$ part of a second.

APPENDIX C.

The negatives, from parts of the Caverns of Luray, of which photographs were exhibited, were taken in the year 1882, by Mr. C. H. James, of Philadelphia.

The pictures intended for the stereo, on 5 x 8 plates, were made with a pair of Dallmeyer's quick-acting four and one-half focus single view lenses; those on 7 x 9 plates, with an eight-inch focus Ross portable symmetrical lens, and the large 18 x 22 plates,

with an eighteen-inch focus Ross portable symmetrical lens, almost all the pictures being taken with the smallest stop of the respective lenses. The exposures with the first named averaged two and one-half hours, the 7 x 9 three and one-half, and the 18 x 22 as much as eight hours.

The focussing was difficult, and accomplished by means of a lighted candle set upon such spots as it was desired to photograph.

The illumination by which the pictures were made, was supplied by the Thomson-Houston arc lights, with which all the most frequented parts of the cave are furnished. These are supplied from the dynamo in an engine house at the hotel, at a distance of nearly a mile from the cave, communication being kept up between the operator and the engineer by telephone.

The power of the light was estimated at 3,000 candles, and in all cases where the character of the subject required more than one of the lamps, the greatest care was taken in the management of the illumination, which was reënforced by the use of a screen or partial reflection of white paper immediately behind the lamp, so as to break up the light, modify and deprive it of its extreme harshness. Much of the success was attributed to the skilful use of this device. Indefatigable patience and hard work was required to obtain successful results.

Mr. James found the electric light exceedingly deceptive, for in many cases when but little or nothing could be seen upon the ground focussing glass of the camera, comparatively short exposures gave good negatives.

The pictures were all taken upon gelatine dry plates.

1884–INTERNATIONAL ELECTRICAL EXHIBITION–1884

FRANKLIN INSTITUTE, Philadelphia, Pa.

Report of Examiners of Section XXV, on the "Application of Electricity to Musical Instruments."

(Issued as a Supplement to Section XXVI.)

REPORT.

There was only one exhibit in this class, viz., the Roosevelt electric organ. Electricity is made to perform all the work of the "action." The "trackers," "rollers," "stickers" are dispensed with in the key action, and the various levers, etc., in the stop action, thus securing extreme simplicity, and consequently little liability to get out of order, and making it possible to place the key-board at any distance from the organ, and even move it from place to place if desired. The current is supplied by a Leclanché battery, and is utilized as follows: A row of electro-magnets, one for each key, is placed under the pneumatic valves that open the pallets. The armatures are attached to the pneumatic valves. When the key is depressed, the circuit is closed, causing the magnet to attract the armature, thus opening the pneumatic valve. When the circuit is broken, the pneumatic valve is closed instantly by a spring. The device for closing the circuit consists of the following parts: (1.) On the under-side of the key is a thin vertical strip of brass. (2.) A strip of wood passes horizontally across the keys, furnished with small brass buttons—two to each key—to which the wires from the battery are attached. When the key is depressed, the vertical strip of brass slides from the upper to the lower button, thus forming a metallic connection, and closing the circuit. A similar device is applied to the draw stops, pedals, combinations and couplers.

H. A. CLARKE,
Chairman of Committee.
RICH. ZEIKWER.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XXIII.

(SECTION IV-A, CLASS VIII, OF THE CATALOGUE.)

Electro-Medical Apparatus,

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, MAY, 1886.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1886.

EDITING COMMITTEE.

1884–INTERNATIONAL ELECTRICAL EXHIBITION–1884

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXIII.—ELECTRO-THERAPEUTIC APPARATUS.

To the Board of Managers of the FRANKLIN INSTITUTE:

GENTLEMEN:—I have the honor to transmit herewith the report of Section XXIII, upon "Electro-Therapeutic Apparatus."

Respectfully,

M. B. SNYDER,

Chairman Board of Examiners.

PHILADELPHIA, September, 1885.

PROF. M. B. SNYDER,

Chairman Board of Examiners, International Electrical Exhibition:

DEAR SIR:—I have the honor to transmit the report on "Electro-Therapeutic Apparatus," as embraced under Section XXIII.

I remain yours respectfully,

HARRISON ALLEN,

Chairman Section XXIII.

PHILADELPHIA, September 16, 1885.

REPORT.

The committee has the honor to report:

That the first exhibit examined, was that of Mr. Otto Flemming, 1009 Arch Street, Philadelphia.

In this exhibit are shown an elaborate sixty cell cabinet battery; a wall cabinet for attachment to a stationary gravity battery; a thirty cell combined galvanic and faradic portable battery; a twenty cell galvanic battery; four sizes of faradic batteries; pedal rheotome; unpolarizable electrodes, etc.

EXHIBIT A.

FLEMMING'S CABINET BATTERY (SIXTY CELL.)

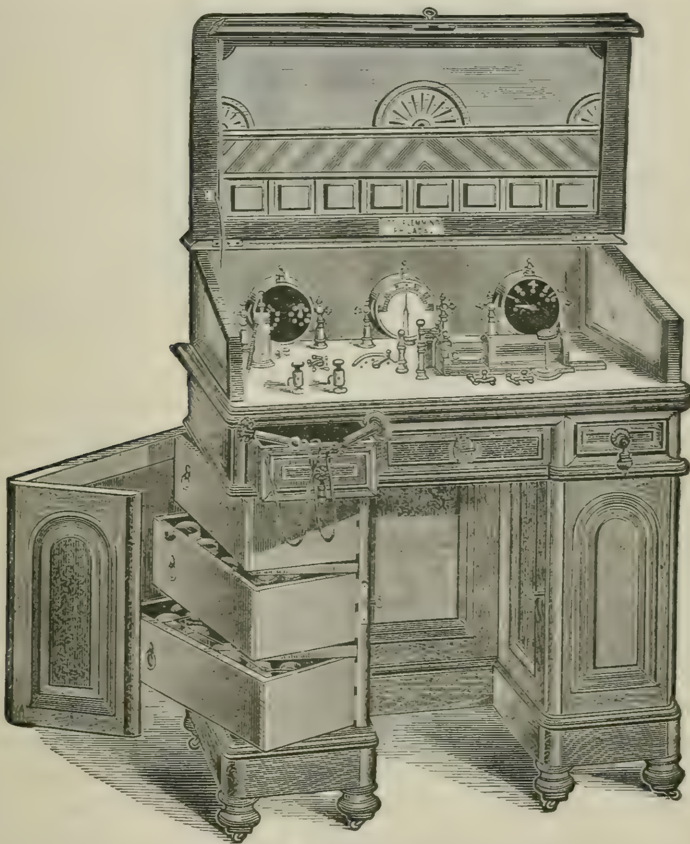
The cells of the battery are described by the manufacturer as follows: The elements are composed of zinc and carbon, the latter mixed with peroxide of manganese, granulated and placed in a glass jar to fill one-third of its capacity. In the centre of the jar is placed a glass tube, also filled with the carbon-manganese mixture, and a carbon rod with platinum wire connection (anode) so that the mixture in the centre glass tube is in unbroken contact with the mixture in the outer glass jar. A diaphragm is formed by tightly packing paper pulp on top of the carbon-manganese mixture, which is covered with a saturated solution of ammonium chloride and a zinc ring for cathode.

The objections to the modified Leclanché cell used by Mr. Flemming, are that it exposes too much surface for evaporation and is unnecessarily complicated in structure. The committee does not believe that the modifications are improvements, but the cell was referred for examination to Committee 14, from whose report the following figures are extracted: Cell No. 1, electro-motive force, 1·45 volts; internal resistance, 11· ohms; current strength in ampères at intervals of minutes at the start, ·12; after two minutes ·09. Cell No. 2, electro-motive force, 1·39 volts; internal resistance, 11.

The key-board of the cabinet battery contains an automatic mechanical rheotome, for interrupting the galvanic current, one, two, four, eight, or sixteen times a second; a galvanoscope, a wire rheostat, formed of a series of Siemens' resistance coils, a Du Bois-Reymond coil, with rapid and slow interruptions to the faradic current; the outer secondary helix being moved by a governing

screw, thus easily adjusting the currents. There is also a watre rheostat, furnishing resistance to the faradic current, and a commutator, changing the polarity of either the galvanic or the faradic current. A Grenet cell furnishes power for the faradic apparatus.*

The key-board of the faradic coil is well deserving of unqualified commendation. The special points to be commended are the



Sixty-Cell Cabinet Battery. (Flemming.)

appliances chosen for slow and rapid interruption of the faradic current, which are superior to any others examined by the committee, in that they give a much greater range in the rapidity of

* The descriptions of apparatus furnished by the committee, are usually modifications, or condensations, of those given by the manufacturers themselves.

movement, and are more rapidly and easily adjusted. The slowest rate obtained was forty per minute, whilst in rapidity, the slow rheotome could be made to approximate that of the rapid spring rheotome. The regulating screw of the faradic coil is a decided convenience, and the commutator is to be commended as durable and not likely to give trouble by getting out of order, but is considered inferior to the modification of the pole changer (in which the tires on the discs extend on one-quarter of a circle) used by Mr. Flemming on his portable galvanic battery, inasmuch as the latter admits of a more perfect break in the circuit.

The galvanoscope, which is useful to show that the circuit is made, does not afford any accurate measure of the power of such current, and in the complete galvanic table, it should be replaced by a dead-beat galvanometer, calibrated in milli-ampères.

There are two rheostats on the key-board, either of which ought to be so arranged as to be sufficient. The objection to the wire rheostat is its expense.

The fluid of the water rheostat should be a solution having greater conductivity than water; because water is so bad a conductor, that in the practical use of the simple water rheostat, it is almost impossible to avoid shocks when the metal conductors are brought into contact. The same rheostat should be used for both currents.

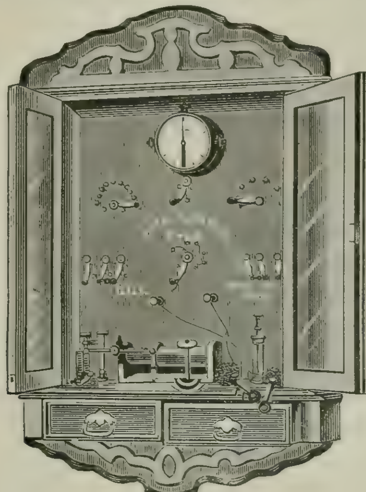
The clock-work rheotome or current interrupter of the galvanic current is condemned as making too prolonged contacts, as being very liable to work irregularly and as offering but a limited range of rate of interruption. It is recommended that the excellent faradic interrupter to be found in the wall cabinet of Mr. Flemming be adopted here also.

EXHIBIT B.

FLEMMING'S WALL CABINET.

In a handsome walnut case, 40 inches high 25 inches wide and projecting 7 inches from the wall is contained a galvanoscope, a commutator, a Du Bois-Reymond coil with rapid and slow interrupter and a contrivance by which the slow rheotome of the Du Bois-Reymond coil can be used to interrupt the galvanic current. There is also a rheostat for both currents and appropriate switches. The key-board of this wall cabinet seems superior to that of Exhibit A,

in that the water rheostat is adapted to both currents and the rheotome automatic. A very valuable feature in this rheotome is that it gives brief periods of current passage with long interrup-



Wall Cabinet. (Flemming.)

tions. The water rheostat should undergo the modifications spoken of under Exhibit A. On account of the small space which it occupies and the ease with which it is kept neat, we believe that this wall cabinet is superior to the ordinary table form of key-board.

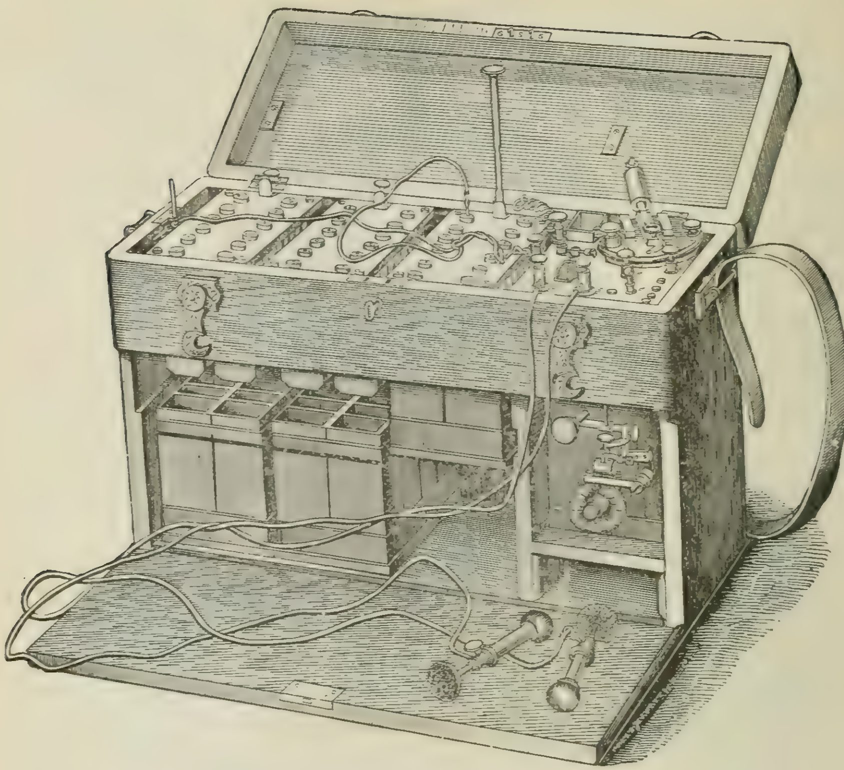
EXHIBIT C AND D.

FLEMMING'S THIRTY-CELL COMBINED BATTERY. FLEMMING'S TWENTY-CELL CONSTANT CURRENT GALVANIC BATTERY.

Both of these batteries are founded on the well-known Stohrer battery, much modified in its mechanical arrangements. It does not seem necessary to give a detailed description of them. Suffice it to say that each is supplied with a hydrostat, which is a rubber-cushioned sliding board, that is kept pressed down on the cells, when the battery is closed and serves to prevent spilling.

In Exhibit C, there is conjoined with the battery a faradic apparatus, provided with both rapid and slow interrupters, which is substantially the No. 3 faradic battery of the same exhibitor.

These batteries in their general mechanical arrangement, and remarkable excellency of workmanship seem to the committee to



Thirty-Cell Combined Battery. (Flemming,)

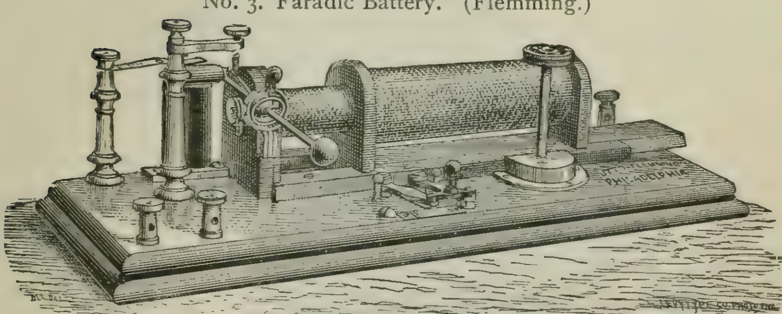
be the best forms of the portable bichromate batteries invented, but in practice they, like all other batteries of their character, are open to serious objections. Among these are the highly corrosive nature of the liquid employed, the closeness of the connections to this fluid, the great ease with which splashing occurs, allowing these connections to become corroded and the fact that the joints by any but the most careful handling are very apt to become loose and allow spilling.

EXHIBITS H, I, J AND K.

H.—Flemming's No. 1 faradic battery,
I.—Flemming's No. 1 faradic battery with slow interrupter.
J.—Flemming's No. 2 faradic battery,
K.—Flemming's No. 3 faradic battery.

These faradic batteries are furnished with the Grenet cell so made that when not in action, the zinc is raised out altogether and the aperture through which it passes securely covered with a rubber hydrostat, making the cell perfectly fluid tight and saving the zinc in transportation or in case of an upset. By this arrangement, the cell can be filled and the zinc immersed for its whole length. This form of cell the committee believe to be well adapted to the needs of the practitioner and commend it highly.

No. 3. Faradic Battery. (Flemming.)



Du Bois-Reymond Induction Coil.

The coils of these batteries are two in number.

The two exhibits, H and J (batteries No. 1 and No. 2), are much inferior to Exhibits I and K (batteries No. 1 with slow interrupter and No. 3), in the complete absence of the slow interrupter and in the inferiority of the rapid interrupter. We do not

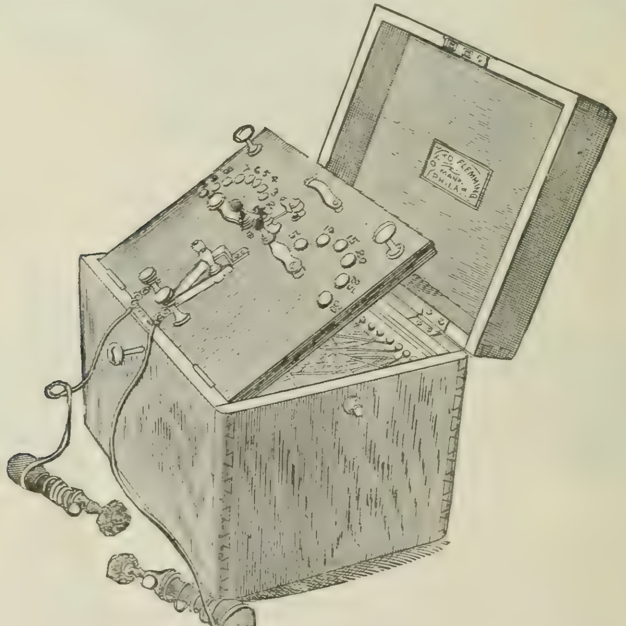
believe that either of these batteries is adapted for use in the physician's office.

Batteries I and K are furnished with interrupters similar to those on which we have commented in speaking of the cabinet battery. In the ease with which the current can be graduated, in the greater power derived from longer coils, in freedom from pretence, in excellency of workmanship, in convenience and general adaptability to the exigencies of daily practice, we know of no faradic battery equal to the battery K of Mr. Flemming; but for many practitioners, the lightness and cheapness of battery I, will give it preference, and the occasions must be rare in which it will not do all that is required of a faradic battery.

EXHIBIT M.

TWENTY-CELL PORTABLE SEALED CONTINUOUS CURRENT BATTERY.

This battery derives its current from a modification of the Leclanché element similar to that described in connection with the cabinet battery (Exhibit A), but in somewhat more compact form.



Leclanché Sealed Battery. (Flemming.)

The cells of this battery were referred to Committee 14, from whose report the following figures are extracted: Cell No. 1, E. M. F., 1·07 volts; internal resistance, 8 ohms; current strength at setting up, ·13 ampère, after one minute ·09, after three minutes ·07. Cell No. 2, E. M. F., 1·46 volts; internal resistance, 13·5 ohms.

The key-board of this battery is furnished with a galvanoscope, a commutator and an arrangement for current selection, similar to that of the cabinet battery of the same manufacturer.

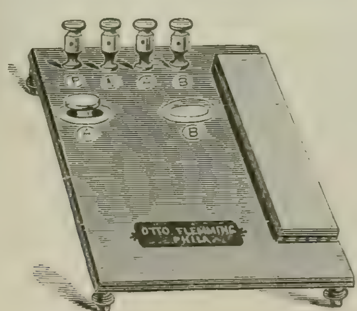
In the absence of corrosive fluid and in permanency and constancy, this battery is much superior to any sulpho-chromate battery. To make it satisfactorily portable would require only that the mechanical arrangement be so altered as to close the cells more perfectly. To adapt it to the full range of medical uses, would require a distinct increase in the number of its elements. In its present form the battery weighs fifteen pounds.

In order to determine the exact value of this battery, the elements were referred to Section XIV.

EXHIBIT N.

MORRIS-LEWIS PEDAL RHEOTOME AND COMMUTATOR.

This instrument is designed to enable the electro-therapeutist



Pedal Rheotome and Commutator. (Flemming.)

to break the current regularly without the aid of the automatic rheotome or a spare hand. We believe that it satisfactorily accomplishes its object.

EXHIBIT O.

UNPOLARIZABLE OR HOMOGENEOUS ELECTRODES.

These are the well known unpolarizable electrodes of Du Bois-Reymond. They are well made, but seem to be better adapted to physiological research than the needs of practical medicine.

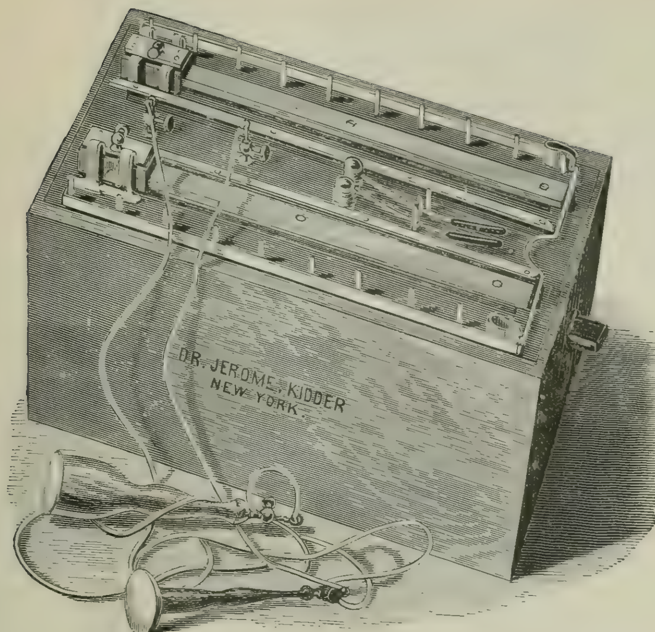
MRS. FRENCH'S BATTERY.

Mr. Flemming also exhibits certain batteries made in accordance with the general plan of his batteries, with the exception that the coils are more numerous, and are composed of various metals. By the varieties of the coils as to length, thickness of wire, and metals employed, it is claimed by the inventor (Mrs. French) that the batteries give rise to forms of current of essentially different physiological powers. The committee can see no reason to believe in the existence of such differences.

Mrs. French's Battery. (Flemming.)

THE KIDDER MANUFACTURING COMPANY, OF NEW YORK—GALVANIC APPARATUS.

The galvanic apparatus of these exhibitors consists of a sulphochromate battery (Battery A), and a large key-board for use with any desired form of cell.



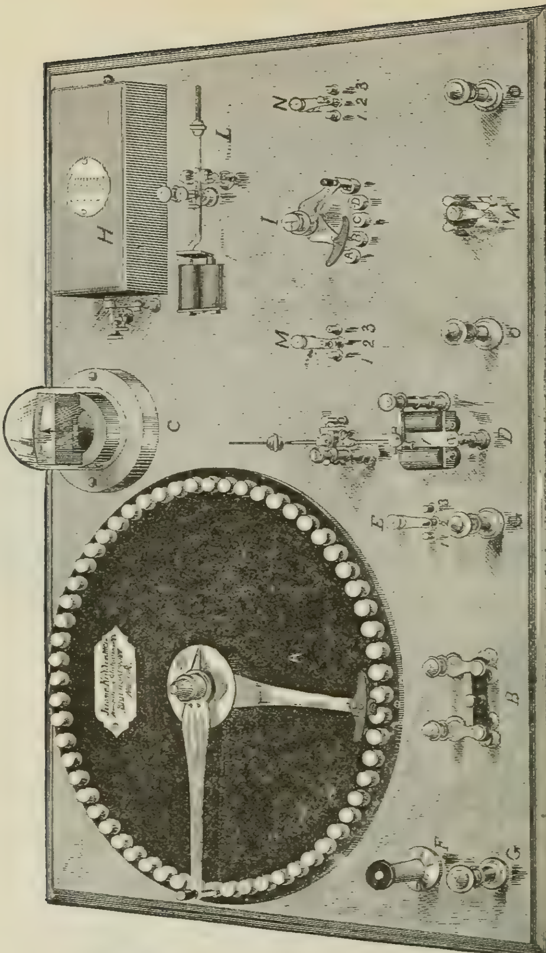
Battery A. (Kidder.)

Battery A is, in its elements and general form of construction, based on the well-known Stohrer battery. The objections to this form of battery have already been stated by the committee. (See Flemming's exhibit.)

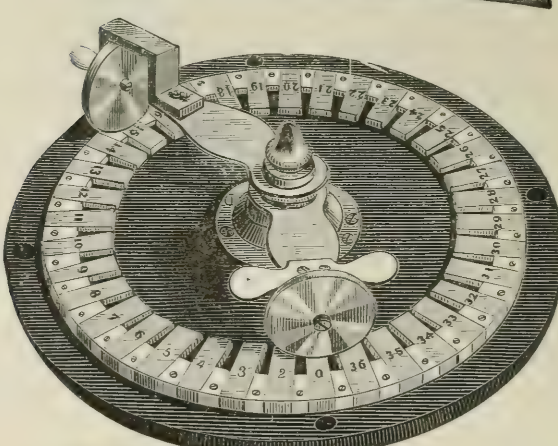
There are certain arrangements of the present battery worthy of commendation. Especially is this so of the selector slide. This is so arranged that by hooking back a spring the cells can be added, so as to make a series of shocks when the current is rapidly increased; and, by loosening the spring, the current can be increased without shock.

This battery is excessively heavy, and as its glass cells are fragile and cannot be closed, it is not at all portable.

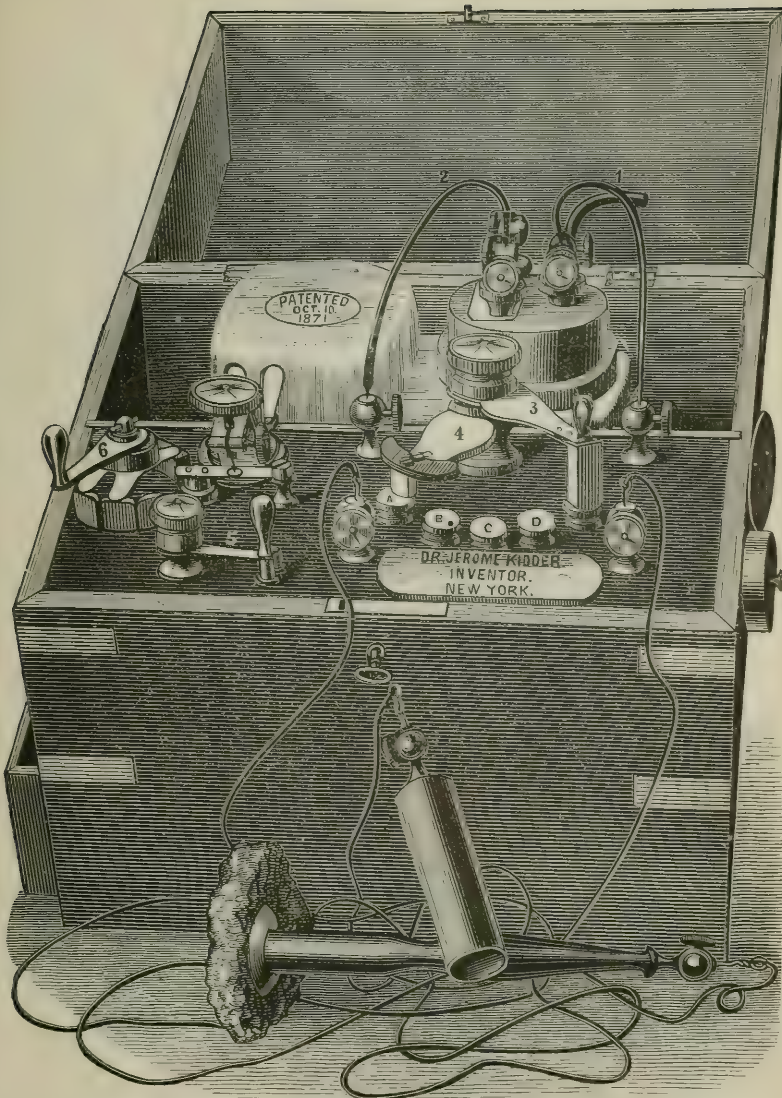
The key-board is adapted either to be placed on the wall or on a table. It is provided with separate commutators and separate terminal posts for the two currents, which duplication is not only unnecessary, but apt to give rise to annoyance. It is furnished with a galvanoscope and an automatic rheotome to interrupt the faradic current. This rheotome is not recommended because the



Stationary Key-board for any desired form of Cell. (Kidder.)



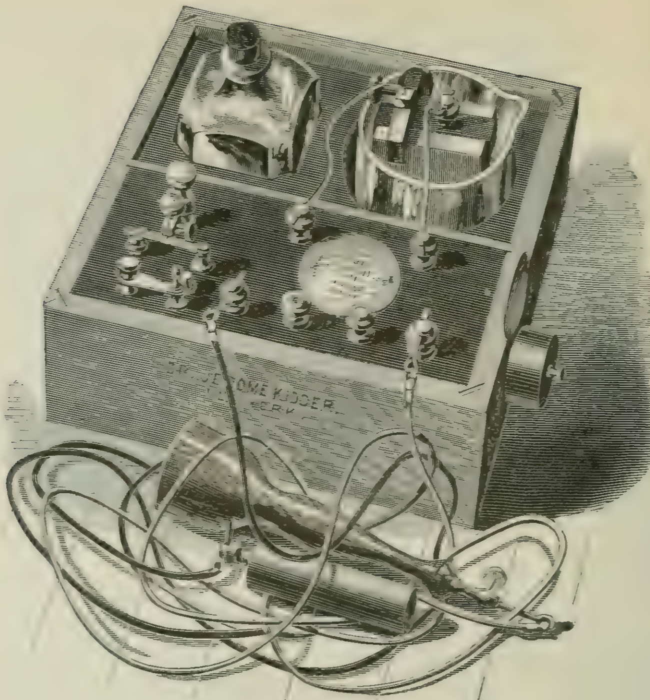
Current Selector for Stationary Battery. (Kidder.)



Large Faradic Apparatus. (Kidder.)

periods of current passage are very long while the interruptions are very brief. The commutator has the serious drawback that it cannot be used as a hand rheotome.

The arrangement for selecting the galvanic cells has the decided advantage of permitting a broken element to be thrown out of the circuit.



Faradic Battery with open Cell. (Kidder.)

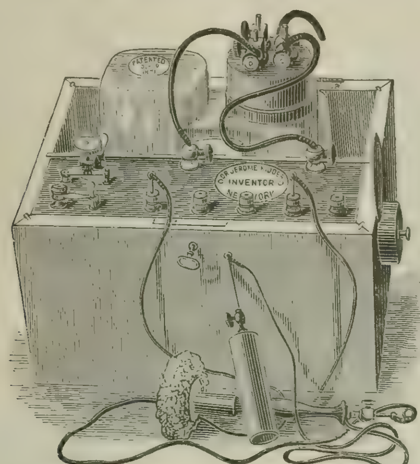
Open Smee Cell. (Kidder.)

There is no galvanometer.

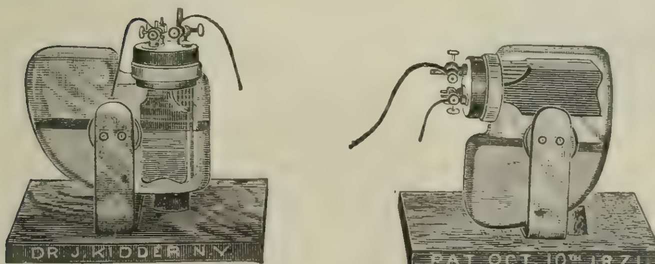
The key-board also contains a faradic apparatus similar to that used in Battery No. 2.

The rheotomes, which are two in number, are of good character, the slowest vibration attained by the exhibitor before the committee was sixty per minute.

Six forms of faradic battery were shown by these makers, varying only in size and strength. They are so entirely wanting



Faradic Battery with Tip Cell. (Kidder.)



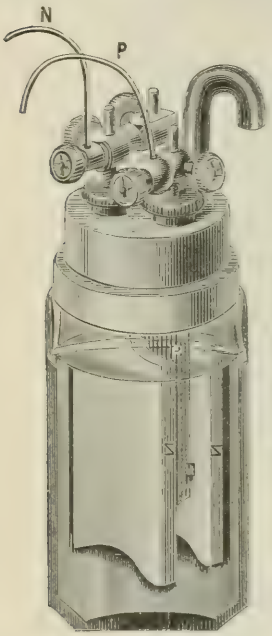
Hydrostatic Tip Cell. (Kidder.)

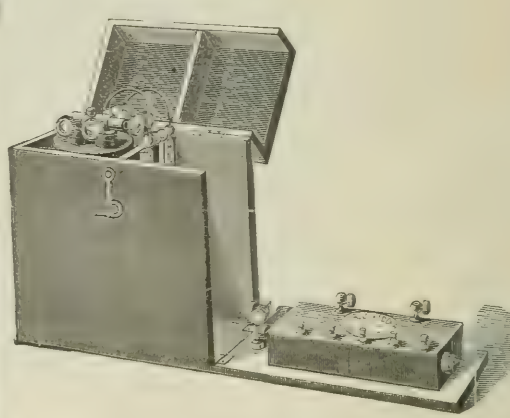
in any form of slow interrupter that in the opinion of the committee they are not adapted to the practical work of the physician.

The cell employed is a modified Smee element. In all, except No. 1 and No. 5, the cells are left entirely open and require emptying of their contents before carriage, or else they are only partially closed. Such an arrangement of elements is intolerable.

Batteries No. I and No. 5 are provided with so-called hydrostatic tip cells which, though large and cumbrous, are sufficiently tight; and when not in use, the elements are exposed only to the vapors and splashings of the acid.

The Smee element is employed in all these batteries. Whilst this is more permanent than the sulpho-chromate cell, the greater electro-motive force of the latter, we believe, recommends it especially for use in portable faradic batteries.





Physician's Visiting Apparatus.
(Kidder.)

Smee Cell. (Kidder.)

The general induction coils, used by the Kidder Company, are composed of three or more coils of wire, each differing in length and diameter, which are joined in the binding posts in such a way that they can be used separately or in unison. It is claimed that from the large No. I battery with four coils, ten galvanic currents of different physiological power can be obtained.

The following, in their own words, is a description of the points of superiority claimed for their coils by the Kidder Manufacturing Company.

"We have first the primary coil, over which the influence from the battery travels, operating the automatic circuit-breaker

(rheotome), and producing a current of great quantity. Wound over the primary and thoroughly insulated is a coil having a greater length and smaller diameter than the primary coil and producing a current of greater intensity and less quantity than the current from the first coil.

"Over the first coil is wound a third coil, having a still greater length than the first and a small diameter, producing a current of still greater intensity than the second coil and of less quantity.

"In the ten-current apparatus we find a fourth coil over the third and the diameter of the wire is very small, while the length is greater than the total of the other three coils combined, producing a current of great intensity and adapted in quality for the relief of pain, etc.

"While the helix or coil is composed of various coils, they can be united so as to form one continuous coil, producing a great variety of qualities for the cure of diseases. The coils are so arranged, according to length and diameters of the wire, as to produce the best results with the battery-power that operates them.

"The influence of the primary coil or the quantity current from the battery can be conducted through the various coils of fine wire, or cut out of the circuit, so as to get the absolute induced currents from the induced coils when desired."

The general coil, in short, is composed of a series of coils, one within the other, all so arranged that they are or can be metallically connected from what is called a "continuous coil" machine. The innermost coil is short and made of thick wire; the next is longer and finer; the third is still longer and finer, and so on to the end of the series.

The number of coils used in the construction of the main coil varies with the size and price of the particular machine; thus one form of apparatus has two coils, another three and another four.

It is claimed that the different parts of this compound, continuous coil, can be so arranged and combined and so tapped, or drawn off for use as to give a large number of different currents or different variations of the qualities of the currents. It is claimed also that these different currents or different qualities of currents, produce different physiological effects, and different effects in the cure of diseases.

Great confusion and misapprehension may arise from the exhibitor's method of speaking of the currents in their various publications, as furnished to the committee. The first current derived from the primary coil is spoken of as "the primary influence," or "primary current," or "galvanic current." The next, "the first induced," etc. The facts being that the current from the first coil (A B), is simply the extra current or primary induced current and the others secondary currents.

It is well known that no galvanic current efficient for any medical purpose can be derived from the single cell of a faradic battery, and that the induced currents derived from coils superimposed upon one another, vary only in tension. All that can be said of this arrangement, is that certain induced currents of varying tension are obtained by the sub-divisions of the coil used. These currents undoubtedly vary in tension, but we were not able to obtain any clear evidence that these currents varied in their practical therapeutic effects.

The coil is one which is well adapted for all the therapeutic purposes for which faradic batteries are commonly used. The current or currents derived from it can be admirably regulated by the arrangement of the binding posts and regulator. The coil has no special disadvantages. What the committee objects to are the excessive claims of these exhibitors.

MR. FLIESCHMAN'S EXHIBIT.

The committee examined one continuous battery of this maker. It was made upon the general principles of the Stohrer battery, and is open to all the objections urged against this form. The mechanism appeared to be good, and we especially commend the simple arrangement by which a defective cell can be thrown out of the circuit and the current be increased cell by cell without shock.

The so-called large double cell pendulum battery is the chief faradic exhibit of Mr. Fleischman. The following claims are made for it by the exhibitor. A very regular and grateful current; the use of the pendulum interrupter, which requires very little power to keep in regular motion, when at rest is nearest the magnetic pole, has no loose connections, and that the coils are so arranged that there is a galvanic current in the primary current circuit.

The committee here reiterates what it has already said, that no efficient galvanic current can be derived from a single cell.

This battery certainly furnishes currents of very great power, but it appears to the committee to be lacking in delicacy, as is required in some departments of electro-therapeutics.

The sulpho-chromate galvanic element used is closed simply by an india-rubber cork, which is not retained by any mechanism, and is in our opinion liable to displacement. This greatly endangers the battery from the escape of corrosive fluid during transportation.

The so-called pendulum interrupter or rheotome is considered very worthy of commendation. It has the great advantage of having no joints to get out of order, and vibrates very steadily. The slowest vibrations claimed by the exhibitor before the committee were 112 per minute.

EXHIBIT OF MR. A. PARTZ.

The medical exhibit of Mr. Partz consists of a portable medical voltaic battery, which is described by the exhibitor as follows: It consists of fifteen tightly closed elements, 1⅝ inches square and 4½ inches high, applicable either together or in sets of three, six, nine and twelve, and contained in a box 6 inches high, 6 inches wide and 11¾ inches long, the whole weighing fourteen pounds. The electrodes are rods of zinc and carbon, the latter having been subjected to a peculiar chemical treatment having the effect of retarding polarization. The excitant liquid consists of a compound solution of about fifteen parts of chloride of zinc, and twenty-five parts of bichromate of ammonium in 100 parts of water.

For this battery, the following claims are made: The initial electro-motive force, as determined by Mr. A. Gaiffe, for one element is 1·65 volts; and after partial polarization through shunting, Count du Moncel and M. Hospitalier found its force to be 1·45 volts. (*La Lumière Electrique*, t. III, p. 168.)

The battery contains no acid, is free from all "local action," and may be kept in daily use for over a year without anything being done to it, provided that it be not unnecessarily exhausted by "short-circuiting;" that is to say, by placing the poles in contact without a part of the human body being inserted in the circuit.

In order to arrive at a positive conclusion concerning this

battery, it was referred to the Battery Committee, which reports as follows:

Cell No. 1, E. M. F., 1·22 volts; internal resistance, ·8 ohm; current strength at setting up, ·42 ampères; after two minutes, ·39; after four minutes, ·39; after six minutes, ·27; after eight minutes, ·24. Cell No. 2, E. M. F., 1·6 volts; internal resistance, ·45 ohms.

Various galvanic belts were examined by the committee, but none of them have sufficient galvanic power to exert any influence even upon the human skin and certainly not upon the organs beneath it, and we believe that they can only do good by acting upon the imagination of the patient.

H. C. Wood, *Chairman*,
Chas. K. Mills,
Jas. Hendrie Lloyd,
G. Granville Faught,
Louis H. Spellier,
G. Betton Massey, *Secretary*.

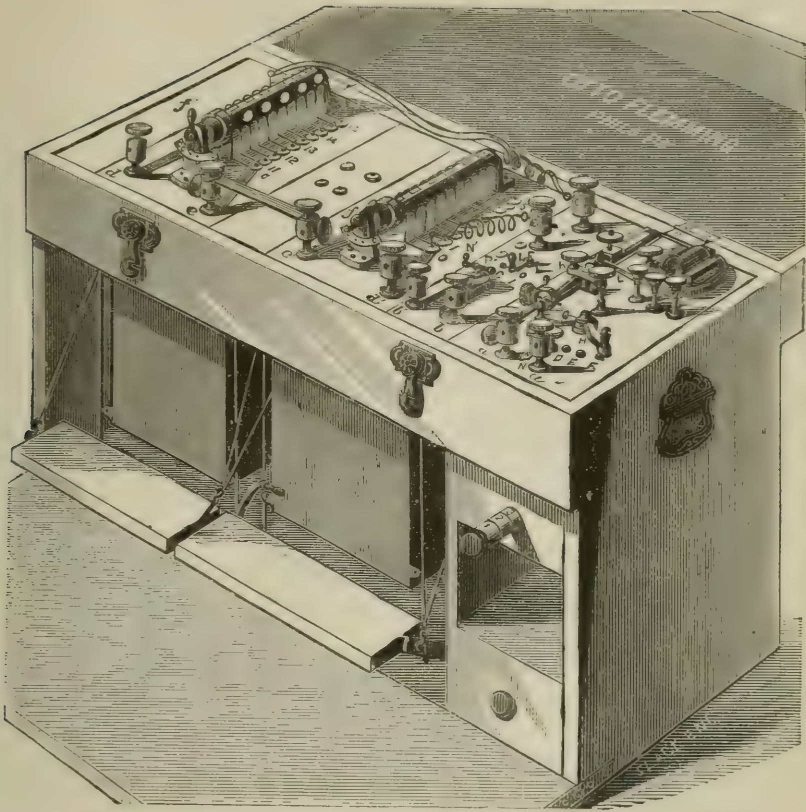
Members of the Sub-Committee on Therapeutic, Galvanic and Faradic Apparatus.

CAUTERY BATTERIES.

The single Cautery battery, upon which the sub-committee will report, is the Universal battery of Mr. Otto Flemming.

The novelty of the movement, as Mr. Flemming states, consists of two systems of ten-zinc and of ten-carbon plates, each of which is suspended from two hard rubber platforms. A brass spring is connected to each plate by a screw, which passes through the platform and presses against a cylindrical commutator. In the lower portion of the box are placed two hard rubber cups, which are partitioned off into ten compartments each. Each cup contains a mixture of bichromate of potassium, sulphuric acid and water. The cups are placed directly beneath the system of suspended plates, and are immersed in the fluid when the treadle is depressed.

The advantages of the battery are pronounced. It can be managed without the assistance of an attendant. It is easily kept



Universal Battery. (Flemming.)

in efficient order, and seldom disappoints the expectations of the operator. The contact of the liquid with the zinc and carbon plates (being dependent upon the movement of the foot) determines both the degree of activity of the elements and the length of time they have been brought in contact.

HARRISON ALLEN,
C. SEILER.